3.5 to 21 kVA N+1 Inverter Owner's Manual

MGE UPS SYSTEMS

IMPORTANT SAFETY INSTRUCTIONS

SAVE THESE INSTRUCTIONS This manual contains important instructions for all static inverters, that must be followed during installation, operation, and maintenance of the equipment.

WARNING

Opening enclosures expose hazardous voltages. Always refer service to qualified personnel only.

ATTENTION

L'ouverture des cabinets expose des tensions dangereuses. Assurez-vous toujours que le service ne soit fait que par des personnes qualifiees.

WARNUNG!

Das öffnen der Gehäuse legen gefährliche Spannungen bloss. Service sollte immer nur von qualifizierten Personal durchgeführt werden.

WARNING

As standards, specifications, and designs are subject to change, please ask for confirmation of the information given in this publication.

ATTENTION

Comme les normes, spécifications et produits peuvent changer, veuillez demander confirmation des informations contenues dans cette publication.

WARNUNG!

Normen, Spezifizierungen und Pläne unterliegen Anderungen. Bitte verlangen Sie eine Bestätigung über alle Informationen, die in dieser Ausgabe gemacht wurden.

NOTE

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at user's own expense.

WARNING

To reduce the risk of fire or electric shock, install in a temperature and humidity controlled indoor area free of conductive contaminants.

This equipment is intended only for installations in a RESTRICTED ACCESS LOCATION.

ATTENTION

Pour réduire le riske d'inccendie ou d'électrocution, installer dans une enciente intérieure contrôlée en température et humidité et sans contaminants conducteurs.

Ce matériel est destiné seulement pour des installations dans un EMPLACEMENT RESTREINT d'cAccès.

WARNUNG!

Um die Gefahr von Feuer und elektrischem Schock zu reduzieren, muss das Gerät in einem temperatur - und feuchtigkeitskontrollierten Raum, frei von leitungsfähigen Verunreinigungen, installiert werden. Dieses Gerät ist nur für die Installation an einem Ort mit eingeschränkter Zugangserlaubnis vorgesehen.

Diese Ausrüstung ist nur für Anlagen in einem EINGESCHRäNKTEN ZUGRIFF STANDORT bestimmti.

WARNING

HIGH LEAKAGE CURRENT. Earth connection essential before connecting supply.

ATTENTION

COURANT DE FUITE ELEVE. Raccordement a la terre indispensable avant le raccordement au reseau.

WARNUNG!

Hoher Ableitstrom Vor Inbetriebnahme Schutzleiterverbindung herstellen.

This manual covers these models:

Product:	*List number:*	*Comcode reference:*	*Rating:*
64034		*407-607-853*	*3.5 kVA*
64074			*7.0 kVA*
64104			*10.5 kVA*
64144			*14.0 kVA*
64174			*17.5 kVA*
64214			*21.0 kVA*

3.5 kVA to 21.5 kVA Inverter Owner's Manual

For service call
1-800-523-0142

86-153460-01 X1 03/02
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MGE UPS SYSTEMS

3.5 to 21 kVA N+1 Inverter Owner's Manual

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Revision History

3.5 to 21 kVA N+1 Inverter Owner's Manual
86-153460-01
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Revision: X0 12/2001
Revision: X1 RND-000999 03/2002

Contents

section		description	page
		Important Safety Instructions	Inside Front Cover
		Technical Support	iii
		Warranty	iv
		Service & Factory Repair	iv
		Property Rights Statement	iv
		Revision History	iv
		Table of Contents	v
		How to Use This Manual	ix
Chapter I - Introduction			
1.0		Scope	1-1
1.1		General Description	1-1
1.2		Standard Product	1-2
1.3		Electrical Specifications	1-3
	1.3.1	DC Input	1-3
	1.3.2	AC Output (per module)	1-3
	1.3.3	Efficiency	1-3
	1.3.4	Power Factor	1-4
	1.3.5	Total Harmonic Distortion	1-4
	1.3.6	Line Regulation	1-4
	1.3.7	Load Regulation	1-4
	1.3.8	Output Frequency	1-4
	1.3.9	Short Circuit Current (SCC)	1-4
	1.3.10	Overload Capability	1-4
	1.3.11	Transient Deviation and Recovery	1-4
	1.3.12	EMI Emission	1-4
1.4		Indicators and Controls	1-4
1.5		Remote Alarm	1-5
1.6		Mechanical Specification	1-6
1.7		Environmental Specification	1-6
	1.7.1	Operating Temperature	1-6
	1.7.2	Shipping Temperature	1-6
	1.7.3	Storage Temperature	1-6
	1.7.4	Operating Humidity	1-6
	1.7.5	Operating Altitude	1-6
	1.7.6	Audible Noise	1-6
	1.7.7	Cooling	1-7
	1.7.8	Thermal Dissipation	1-7
	1.7.9	Safety Approvals	1-7
	1.7.10	Reliability	1-7

section description . . . . . .page

Chapter II - Installation & Operation

2.0 Scope 2-1
2.1 Receiving 2-1
2.1.1 Handling 2-1
2.1.2 Storage 2-1
2.2 Prerequisites to Installation 2-1
2.2.0 Mechanical Mounting 2-2
2.2.1 Location 2-5
2.3 Common Installation Procedure 2-5
2.3.0 Grounding 2-5
2.3.1 Input and Output Cable Connections 2-5
2.3.1.1 AC Input Circuit Breaker 2-5
2.3.1.2 DC Input Circuit Breaker 2-5
2.3.1.3 Connections 2-6
2.3.2 AC Input/Output Voltage Selection 2-7
2.3.3 Software Configuration Set-Up 2-7
2.3.3.1 Dual Processor Set-Up 2-7
2.3.3.2 System Personalization 2-8
2.3.3.3 Redundant Controller Set-Up 2-8
2.3.4 Power Module Installation 2-8
2.3.5 Start-Up Sequence 2-8
2.3.5.1 Power-Up Procedure 2-9
2.3.5.2 Powering Up the Inverters 2-9
2.3.6 De-Energizing the System 2-9

Chapter III - Maintenance

3.0 Scope 3-1
3.1 Safety Instruction 3-1
3.2 Preventive Maintenance 3-1
3.2.1 Preventative Maintenance Procedures 3-1
3.2.2 Dust Removal and Exterior Cleaning 3-1
3.2.3 Air Intake Cleaning 3-2
3.2.4 AC Fan Replacement Procedure 3-2
3.2.5 DC Fan Replacement Procedure 3-2
3.3 Replacement Parts 3-3
3.4 Troubleshooting and Servicing 3-3
3.4.1 Installation Check 3-3
3.4.2 Inverter System Basics 3-3
3.4.2.1 DC Input Circuit Breaker 3-3
3.4.2.2 AC Output Circuit Breaker 3-4
3.4.2.3 Cable Connection and Static Switch Module 3-4
3.4.2.4 ON-LINE Mode 3-4
3.4.2.5 OFF-LINE Mode 3-4
3.4.2.6 Troubleshooting Guide 3-4
3.4.2.7 Inverter Configuration 3-4
3.4.2.8 Battery Booster 3-4
3.4.2.9 Dual Half-Bridge Inverter 3-5
3.4.2.10 Average Current Mode Control 3-5

section description . . . . . page

Chapter IV - Theory of Operation

4.0 Scope 4-1
4.1 "Receiver" Cabinet "Controller" 4-1
4.2 LCD "Display" Panel 4-1
4.3 Alarm Relays 4-3
4.4 Installation "Set-Up" 4-3
4.5 DC Input Power Connections 4-4
4.6 Inverter AC Output Distribution 4-4
4.7 Power Modules 4-4
4.7.1 Power Module Configuration 4-7
4.7.1.1 Battery Input 4-7
4.7.1.1.1 Battery Booster Operstion 4-7
4.7.1.2 Inverter 4-8
4.7.1.2.1 Dual Inverters 4-8
4.7.1.2.2 Inverter Output 4-8
4.7.1.2.3 Inverter Control 4-8
4.7.1.2.4 Average Current Mode 4-9
4.7.1.2.5 Inverter Sweep Generator 4-9
4.7.1.2.6 Fault Detection 4-9
4.7.1.2.7 Internal Power Supply 4-10
4.8 Controller 4-10
4.8.1 "Controller" Power Supply 4-10
4.8.1.1 "Controller" Input Signals 4-11
4.8.1.2 DC Current Measurement 4-11
4.8.1.3 Analog Inputs 4-11
4.8.1.4 Digital Inputs 4-12
4.8.1.5 Alarm Relays 4-12
4.8.1.6 "Watch Dog" Timer 4-12
4.8.1.7 High Voltage Drivers 4-13
4.8.1.8 Under Voltage Detector 4-13
4.8.1.9 Sine Wave Reference 4-13
4.8.1.10 "Display" Driver 4-13
4.8.1.11 "Controller" Selection 4-13
4.8.2 Static Switch 4-13
4.8.2.1 Static Switch Driver 4-14
4.8.3 Current Sensing 4-14
4.8.3.1 Output Sensing 4-14
4.8.3.2 Back-Feed Current Sensor 4-14

Glossary

. . . . . g-1

Figure Description . . . . . Page

1-1 System Configurations 1-2
2-1 Installation Drawing, 7 kVA Inverter System 2-3
2-2 Front View, 7 kVA, System Component Description 2-4
2-3 Static Switch Jumper Positions 2-6

Figure	Description	Page
3-2	Dual Inverter and Waveform Diagram	3-5
4-1	Block Diagram of the 21 kVA Inverter System	4-2
4-2	Block Diagram of the S4 Inverter Power System	4-3
4-3	Block Diagram of Power Module	4-5
4-4	Voltage and Current Waveforms of DC/DC Battery Booster	4-6

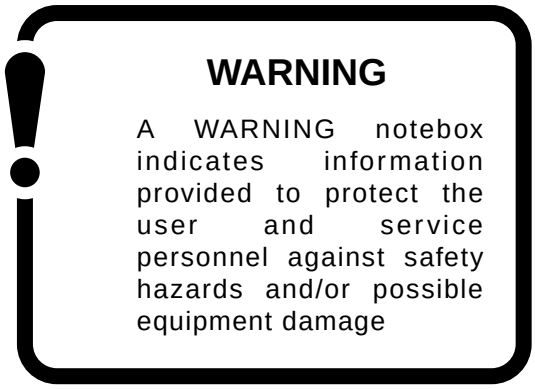
Table	Description	Page
1-1	Inverter System Characteristics	1-2
1-2	Inverter Module Dimensions	1-3
1-3	S4 AC Output Current Ratings	1-3
1-4	Alarm Connections	1-6
1-5	S4 Receiver Cabinet Mechanical Dimensions and Weights	1-6
3-1	Installation Checklist	3-3
3-2	Troubleshooting	3-4

How To Use This Manual: This manual is designed for ease of use and easy location of information.

To quickly find the meaning of terms used within the text, look in the Glossary.

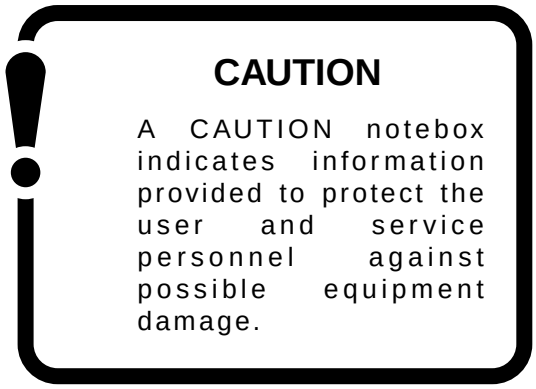
To quickly find a specific topic, look in the Index.

This manual uses Noteboxes to convey important information. Noteboxes come in four varieties:



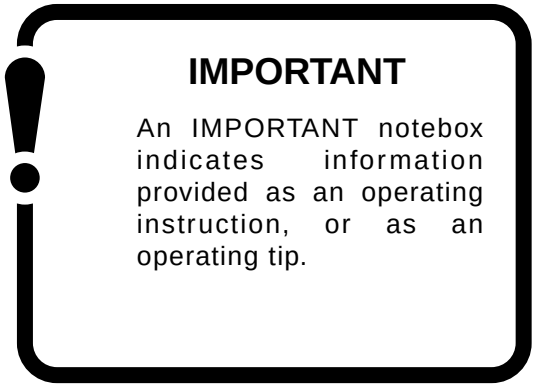
WARNING

A WARNING notebox indicates information provided to protect the user and service personnel against safety hazards and/or possible equipment damage



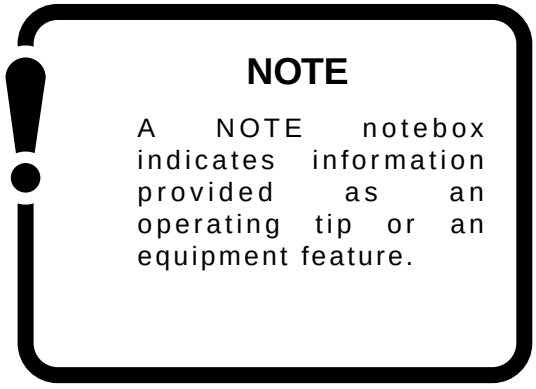
CAUTION

A CAUTION notebox indicates information provided to protect the user and service personnel against possible equipment damage.



IMPORTANT

An IMPORTANT notebox indicates information provided as an operating instruction, or as an operating tip.



NOTE

A NOTE notebox indicates information provided as an operating tip or an equipment feature.

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Introduction

WARNING

An AC output will be present at the output terminals immediately when AC input is energized.

ATTENTION

La tension alternative de sortie appara ît dès la mise sous tension de l'entrée.

WARNUNG

Eine Ausgangsspannung liegt an den Ausgangsklemmen, sobald der Netzeingang angeschlossen wird.

1.0 Scope

This manual provides technical information for installation, operation, and maintenance of MGE UPS Systems' modular inverter systems series ranging from 3.5 kVA to 21 kVA. Please read this manual thoroughly before installing and operating the system. Please retain this manual for future reference.

The manual is divided into four sections:

Section I — Introduction

This section introduces the S4 3.5 to 21 kVA static inverters, including a general description of the inverter and its components, and inverter specifications.

Section II — Installation & Operation

This chapter describes installation of the inverters, including receiving, handling, and storage procedures; prerequisites to the installation; installation procedures; and start-up procedures.

Section III — Maintenance

This section describes maintenance of the inverters, including preventive maintenance routines, and recommended spare parts.

Section IV — Theory of Operation

An appendix provides a glossary of technical terms at the end of this manual provides definitions of terms used within the text. An index makes it easy to quickly locate topics of interest.

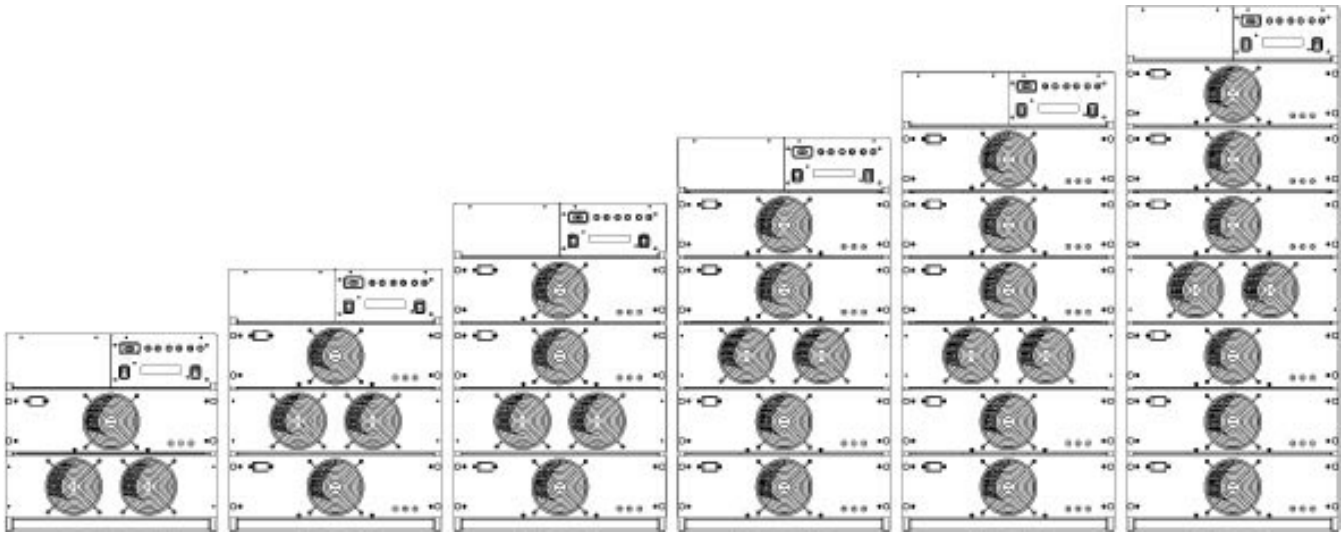
1.1 General Description

This static, modular inverter system series provide stable, distortion-free AC power from a DC input source at a selectable output voltage and frequency prior to shipment, for sensitive equipment which must be operated in

locations where commercial AC power is not available. With a built-in static transfer switch, the inverter also forms a reliable and economical part of uninterruptible power supply systems in either on-line or off-line mode. See chapter 8, Theory of Operation, for detailed information on inverter characteristics. This series employed modular design to provide N+1 redundancy, and twin controller cards to double reliability. There are three distinctive parts in these tower inverter systems. The top part is a built-in module that houses the twin controller, alarm cards, LCD unit, and LED indicators. The center part is a built-in module that houses a static transfer switch, and where input and output connectors are located. It is easily recognized by twin fan front panel. Above and below this static switch module are individual inverter modules rated 3.5 kVA/3kW each (those with single fan front panel).

Topaz S4 systems are available in six receiver cabinet configurations housing 1 to 6 inverters, a static transfer switch console and redundant microcontroller modules.

Figure 1-1: System Configurations



3.5 kVA | 7 kVA/3.5 kVA N+1 | 10.5 kVA/7 kVA N+1 | 14 kVA/10.5 kVA N+1 | 17.5 kVA/14 kVA N+1 | 21 kVA/17.5 kVA N+1

1.2 Standard Products

Consult table 1 below for the system(s) you are working on.

Table 1-1: Inverter System Characteristics

Part Number	Power rating (kVA)	Nominal Input Voltage (VDC)	Input Voltage Range (VDC)	Maximum Input Current @ -40VDC (Amperes)	Nominal Output Amperes at selectable output voltage of: 120	220	230	240	Selectable Output Frequency Hz
64034	3.5	(-48)	(-40 to -60)	88	29	16	15	14.5	50 or 60
64074	7	(-48)	(-40 to -60)	176	58	32	30	29	51 or 60
64104	10.5	(-48)	(-40 to -60)	265	87	48	45	43.5	52 or 60
64144	14	(-48)	(-40 to -60)	353	116	64	60	58	53 or 60
64174	17.5	(-48)	(-40 to -60)	441	145	80	75	72.5	54 or 60
64214	21	(-48)	(-40 to -60)	529	174	96	90	87	55 or 60

Table 1-2: Inverter Module Dimensions

Inverter Module	HEIGHT (in/cm)	DEPTH (in/cm)	WIDTH (in/cm)	WEIGHT (lb/kg)
64004-9MSK1	5.18 / 13.3	15.12 / 38.85	15.76 / 40.5	46 / 20.44

Note: Weight: 1 six-mod receiver = 135 lbs. 1 UPS Module = 46 lbs.

Total System Weight, 21 kVA system = 411 lbs.

1.3 Electrical Specifications

Electrical Specifications are subject to revision without notice.

1.3.1 DC Input

Nominal: -48Vdc; Operating Range: -39.5Vdc to -60 Vdc

NOTE

An external DC circuit breaker or fuse should be used at the DC source.

1.3.2 AC Output (per module)

Voltage:	120Vrms	or	240Vrms
Current:	25Arms	or	12.5Arms
Frequency:	50Hz	or	60Hz

Table 1-3: S4 AC Output Current Ratings

UNIT	3.5 kVA AC AMPERES)	7 kVA (AC AMPERES)	10.5 kVA (AC AMPERES)	4 kVA (AC AMPERES)	17.5 kVA (AC AMPERES)	21 kVA (AC AMPERES)
VAC						
100*	27.3	54.5	81.8	109.1	136.4	163.6
110	27.3	54.5	81.8	109.1	136.4	163.6
115	26.1	52.2	78.3	104.3	130.4	156.5
120	25.0	50.0	75.0	100.0	125.0	150.0
200	15.0	30.0	45.0	60.0	75.0	90.0
220	13.6	27.3	40.9	54.5	68.2	81.8
230	13.0	26.1	39.1	52.2	65.2	78.3
240	12.5	25.0	37.5	50.0	62.5	75.0

* 100VAC version needs to be derated.

1.3.3 Efficiency

85% minimum, 88% typical (on-line mode); 97% typical (off-line mode) at full kVA/Watt load.

1.3.4 Power Factor

Rated kVA is available over a power factor range of 0.6 lagging to 0.6 leading at nominal voltage. Watt rating should not be exceeded.

1.3.5 Total Harmonic Distortion

Less than 1% for linear load conditions, 3% maximum for crest factor loads up to 3:1.

1.3.6 Line Regulation

System output voltage variation, less than 1% over the DC voltage range.

1.3.7 Load Regulation

System output voltage variation, less than 1% from zero to full load at nominal DC input.

1.3.8 Output Frequency

User-selectable, 50Hz or 60Hz. Free run frequency stability shall be within +/-0.02% of the selected frequency.

1.3.9 Short Circuit Current (SCC)

300% minimum of rated load current for four cycles. A SCC is defined as a current that exceeds 150% of rated current.

1.3.10 Overload Capability

Continuous overload up to 108% of rated VA/watts at 40°C maximum.

1.3.11 Transient Deviation and Recovery

Within 20% of average value for any change in output current or step change in input voltage within specified limits. Recovery within 1millisecond from zero to full load

1.3.12 EMI Emission

Less than 30dBrnc.

1.4 Indicators and Controls

See Figure 2-2 on page 2—4 for the location of indicators and control switches.

There are six LED indicators divided into three groups – DS1 and DS2, DS3 and DS4, DS5 and DS6 - on the “Display” front panel. DS1 and DS2 are indicators of controller A; DS3 and DS4 are indicators for controller B; DS5 and DS6 are for output capacitors’ fuse indicators. Failure of output capacitors will trip output fuses, and will activate DS5 and/or DS6 indicators

At power-up, one of the two controller units will be up quicker than the other and will take control the system. Consequently either DS1 (if controller A is in charge) or DS3 (if controller B is in charge) will be on blinking green, signaling that the system output is ready to be turned on.

The inverter output voltage is turned ON and/or to Stand-by via switch SW1 located on the left side of the LCD “Display” Panel. Pushing it up is to turn the inverter ON, and pushing it down is to turn the inverter OFF. WARNING: In the “Stand-by” position, if AC power is applied to the AC input terminal block, AC power will be on the output of the unit. When the output voltage is on, DS2 (or DS3) indicator will be on green steadily, signaling that every thing is normal.

The system measurement information is displayed on the LCD "Display" panel. Switch SW3 is pushed down (or up) to scroll the LCD's screens for more information. Individual inverter module has only one control, an ON/OFF circuit breaker, located at the upper left corner of the front panel. This breaker is used to energize (or de-energize) the inverter module.

Note: The module circuit breakers must be turned on prior to turning the system output voltage on.

LCD Readout

The LCD unit displays two lines (out of a total of seven lines) of information at a time. Each line can be scrolled up (or down) independently by toggling switch SW3. Typical seven lines of information are shown below:

Line 1	INV:	off	normal	Inverter off/on
Line 2	BYP:	static	normal	Static bypass on/normal operation
Line 3	LOAD:	120V	100%	Load % on nominal
Line 4	AC IN:	120V	60 Hz	AC input voltage/frequency
Line 5	DC IN:	48.0V	073.5A	DC voltage/DC current
Line 6	LOAD:	03000 W	025.0A	Load Power (W)/Current (A)
Line 7	INV:	1 of 6	60 Hz	Inverter(s) in operation/frequency

1.5 Remote Alarm

The system provides three alarm signals, namely, Utility alarm, Minor alarm, and Major alarm.

5.1 Utility alarm – Utility alarm is ON when utility input voltage is lost/out of tolerance.

5.2 Minor alarm – The system sends out this signal to indicate something is not functioning properly, but inverter can still maintain the load.

5.3 Major alarm – Whenever load is lost power and the system is energized.

For alarm connection, see Table 1-4.

Alarm Relays

There are three alarm relays. All relays are "form C" type, that is, the relay has a normally open and a normally closed contact set.

The "Major Alarm" relay will be energized when the system is operating properly, that is, power is being supplied to the load either from the Inverter or from the Utility. There are two sets of "form C" contact sets on the "Major Alarm" relay.

The "Minor Alarm" relay will be de-energized, and will be energized for the "alarm" condition. A "Minor" alarm will be issued if the system is not operating properly. Such an alarm will be issued during over load, battery voltage not within specified limits, power modules over temperature and module fault.

The "Utility Alarm" relay will be de-energized during normal operation and will be energized for the "alarm" condition. This alarm will be issued if the utility voltage is not within specified limits or the input frequency is not within proper limits.

The table below shows the "alarm" and the "non-alarm" terminal block connections. This terminal block is located in the top, left side of the receiver cabinet. The small front panel must be removed to gain access to the terminal block.

Table 1-4: Alarm Connections

J21 terminal block screw position ---	1	2	3	4	5	6	7	8	9	10	11	12
MAJOR ALARM ---		X	X									
MAJOR ALARM ---					X	X						
No Major Alarm ---	X	X										
No Major Alarm ---				X	X							
Minor Alarm ---							X	X				
No Minor Alarm ---								X	X			
Utility Alarm ---										X	X	
No Utility Alarm ---											X	X

"X" indicates a short circuit between J21 terminal block points.

1.6 Mechanical Specification

Table 1-5: S4 Receiver Cabinet Mechanical Dimensions and Weights

	MODEL					
	3.5 kVA	**7 kVA**	**10.5 kVA**	**14 kVA**	**17.5 kVA**	**21 kVA**
HEIGHT (in/cm)	15.75 / 40.5	21 / 54	26.25 / 67.5	31.5 / 81	36.75 / 94.5	42 / 107.9
DEPTH (in/cm)	18.5 / 47.5	18.5 / 47.5	18.5 / 47.5	18.5 / 47.5	18.5 / 47.5	18.5 / 47.5
WIDTH (in/cm)	17 / 43.7	17 / 43.7	17 / 43.7	17 / 43.7	17 / 43.7	17 / 43.7
RECEIVER WEIGHT (lb/kg)	67 / 30.4	88 / 39.9	100 / 45.4	111 / 50.3	122 / 55.3	136 / 61.7
RECEIVER + MODULES WEIGHT (lb/kg)	114 / 51.7	182 / 82.6	241 / 109.3	299 / 135.6	357 / 161.9	418 / 189.6
RECEIVER SHIPPING WEIGHT (lb/kg)	78 / 35.8	100 / 45.4	112 / 51.6	123 / 55.8	134 / 60.8	148 / 67.1

1.7 Environmental Specifications

1.7.1 Operating Temperature

All models operate to specifications from 0 to +50° C (+32° F. to +122° F).

1.7.2 Shipping Temperature

-40° C to +75° C (-40° F. to +192° F.) for shipping;

Not recommended for storage.

1.7.3 Storage Temperature

-40°C to +60°C (-40°F to +166°F)

1.7.4 Operating Humidity

0 to 90% relative, without condensation.

1.7.5 Operating Altitude

200 feet below to 10,000 feet above sea level

1.7.6 Audible Noise

Less than 65 dBA per Type 2, IEC and ANSI SI.4, when measured in a 40 dBA environment at a distance of 4 feet from any surface. At nominal ambient (+23C) and 75% load, typical audible noise is 50 dBA in the ON-LINE mode, 56 dBA in the OFF-LINE mode.

1.7.7 Cooling

Forced air. Air intake is through the front of the unit, exhaust out the sides.

1.7.8 Thermal Dissipation

Heat rejection: 602.28 BTU/Hr for each rated KW of the inverter system. This is based on an inverter efficiency of 85% at full load and does not include load dissipation.

kVA rating	3.5	7	10.5	14	17.5	21
Watts	529	1059	1582	2118	2647	3177
BTU/Hr	1807	3614	5421	7227	9034	10841
Est. A/C, TONS	0.151	0.301	0.452	0.602	0.753	0.903

1.7.9 Safety Approvals

Meets UL/CSA 60950 (listed) and European Standard EN60950.

1.7.10 Reliability

Calculated MTBF at 25° C ambient temperature

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Installation & Operation

2.0 Scope

This chapter describes installation of the inverters, including receiving, handling, and storage procedures; prerequisites to the installation; installation procedures; and start-up procedures.

2.1 Receiving

Before accepting the shipment from the freight carrier, inspect the exterior surfaces of all shipping containers or packaging used, and the equipment, for damage that may have occurred during transit. If the shipping containers or equipment shows evidence of damage, note the damage on the receiving document (bill of lading) prior to signing for receipt of equipment.

ALL CLAIMS FOR SHIPPING DAMAGE MUST BE FILED DIRECTLY WITH THE CARRIER. Replacements for damaged components should be ordered through MGE UPS Systems.

2.1.1 Handling

The equipment can be lifted from the top, using the eye-bolts; however, a spreader bar must be used to avoid bending the bolts or the side panels. The equipment may also be handled using a forklift or pallet mover.

2.1.2 Storage

If the equipment is to be stored prior to installation, it should be stored in a cool, dry, well-ventilated location that is protected from rain, splashing water, chemical agents, etc. The equipment should be covered with a tarpaulin or plastic wrapper to protect it against dust, dirt, paint, or other foreign materials.

2.2 Prerequisites to Installation

An efficient installation depends on careful planning and site preparation. Installation of the equipment must be handled by skilled technicians and electricians familiar with the special requirements of high-voltage electrical equipment. The installation must comply with the requirements of the National Electrical Code (ANSI/NFPA 70, latest issue) and local codes as applicable.

We strongly recommend contracting MGE UPS Systems for system start-up. Do not allow unqualified personnel to handle, install, or operate MGE UPS Systems static inverter systems.

NOTE

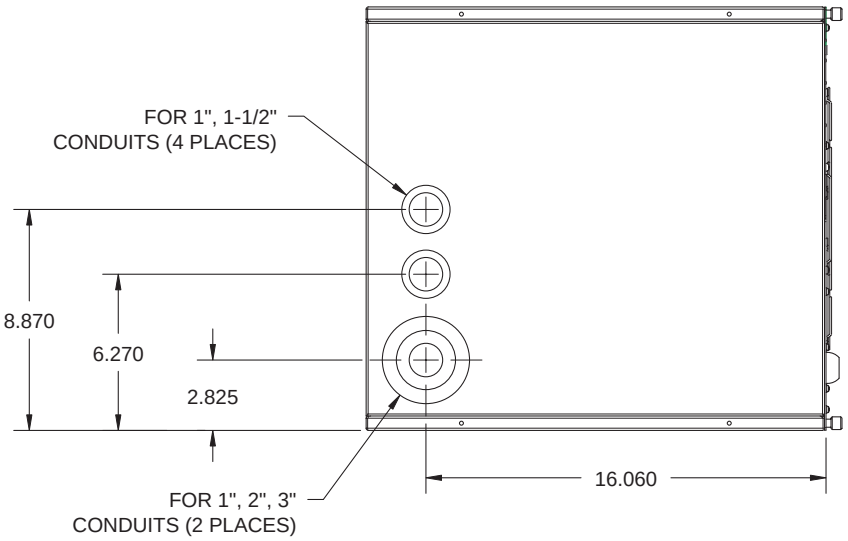
The inverter can be mounted close to a rear wall, because there is no rear access to the unit. All input DC, output AC, and input AC wiring to the inverter enters through the top or left side of the rack assembly. Service to the inverter rack is through the front. If a maintenance bypass unit is installed, rear access is required for this unit.

2.2.0 Mechanical Mounting

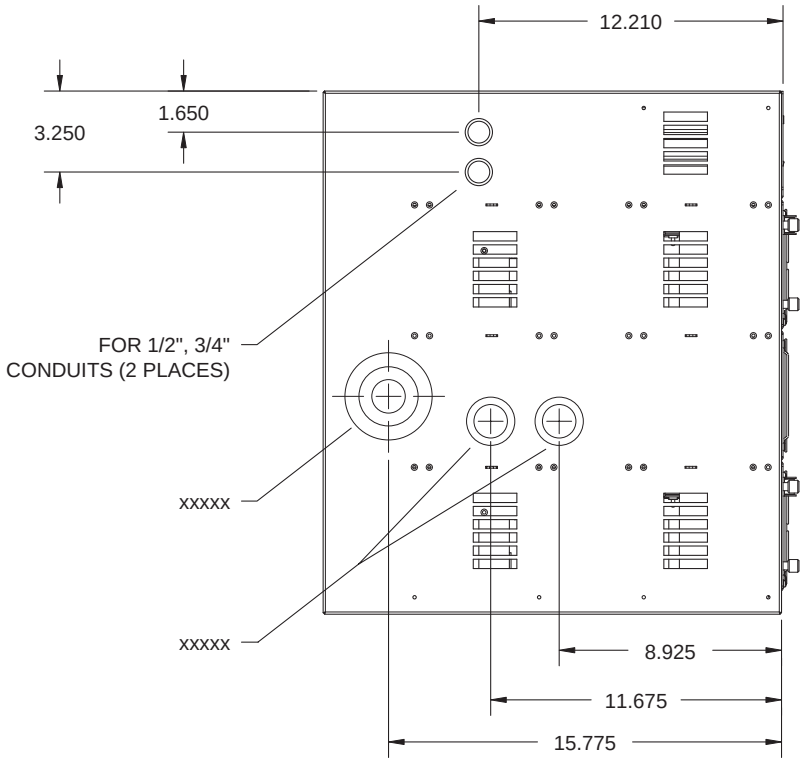
The equipment can be either mounted on a floor, or rack-mounted in a 19”, 23”, or 25” rack. Optional mounting bracket kits can be ordered for rack mounting in a 19” or 23” rack. Ordering information is as follows:

All receivers and inverter power modules are shipped separately from the factory. Receivers will be shipped on a pallet. These receivers can be secured to a floor or to some other permanent base using one-half inch bolts through the four holes in the base supports. The inverter modules will be shipped based on customer’s discretion on power configuration or the size of the receiver they are using. Modules will be shipped separately from exterior chassis. Refer to Figure 2-2 on page 2—4.

Figure 2-1: Installation Drawing, 7 kVA Inverter System

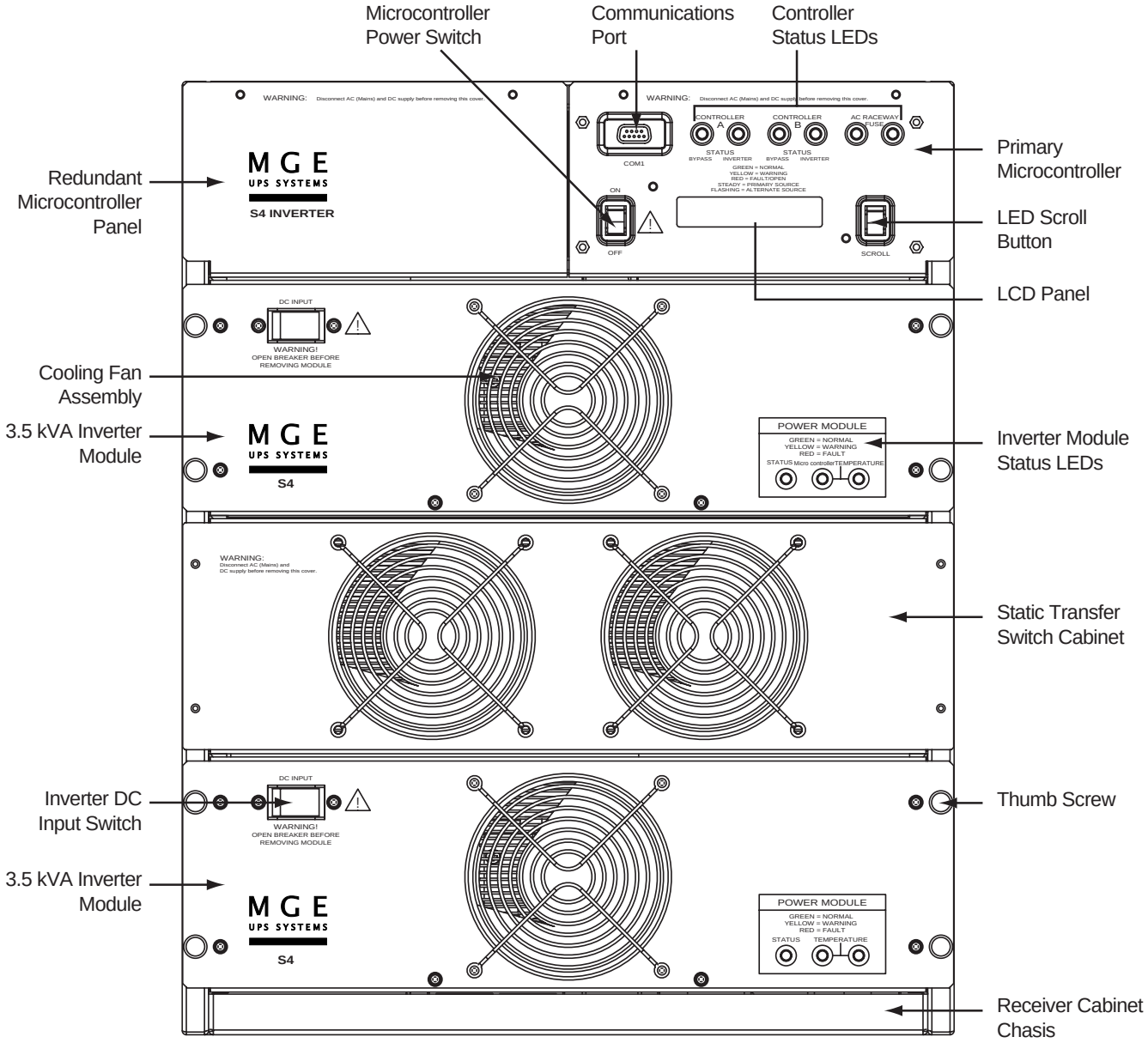


TOP VIEW



LEFT SIDE VIEW

Figure 2-2: Front View, 7 kVA, System Component Description



NOTE: Modules are shipped separately to reveiver cabinet.

2.2.1 Location

The equipment is designed for installation in a protected environment. Factors to be considered in selecting a location include ventilation, temperature, humidity, and accessibility. Install the unit in a clean, dry location with an unrestricted air flow. The equipment is cooled by forced air. Allow at least 6 inches of air space around the equipment for proper cooling.

2.3 Common Installation Procedure

Note: The installation procedure is common with all units.

2.3.0 Grounding

For safety and proper operation of the unit, including maximum attenuation of electrical noise, suitable grounding is required. A separate grounding electrode conductor should be connected from the ground (GND) terminal to a nearby grounding electrode, and should be sized per National Electrical Code Article 250-94. The grounding electrode should be grounded structural metal, a metal water pipe, or a suitable ground rod (National Electrical Code 250-26). The grounding electrode should be as near as possible to the unit. The S4 will accommodate two 1/0 gauge wire. Customer provides grounding system.

Move the "receiver" cabinet to its intended location, using one of the suggested handling methods. After it is in its final position, remove the blank panels from the front of the "receiver" cabinet. Blank panels are supplied with the unit so as to prevent damage to the unit during shipment. Remove these blank panels, but do not discard them. Remove top cover panel on the receiver's "static switch" (cover of the panel with two fans) for access to the wiring area. The connections to be made are the DC input connections, load connections, AC input connections, and optional remote alarm connections. The connection terminals and buss bars are located at the static switch area, which is in the center of the receiver cabinet. For safety, the DC safety ground connection should me connected first, then DC positive (+) connection made next, then the DC negative (-) last.

2.3.1 Input and Output Cable Connections

2.3.1.1 AC Input Circuit Breaker

WARNING

If utility line voltage is connected to the system, an appropriately rated AC circuit breaker MUST be installed between the supplying AC source and the inverter plant. Installation must comply with local/national electrical installation requirements.

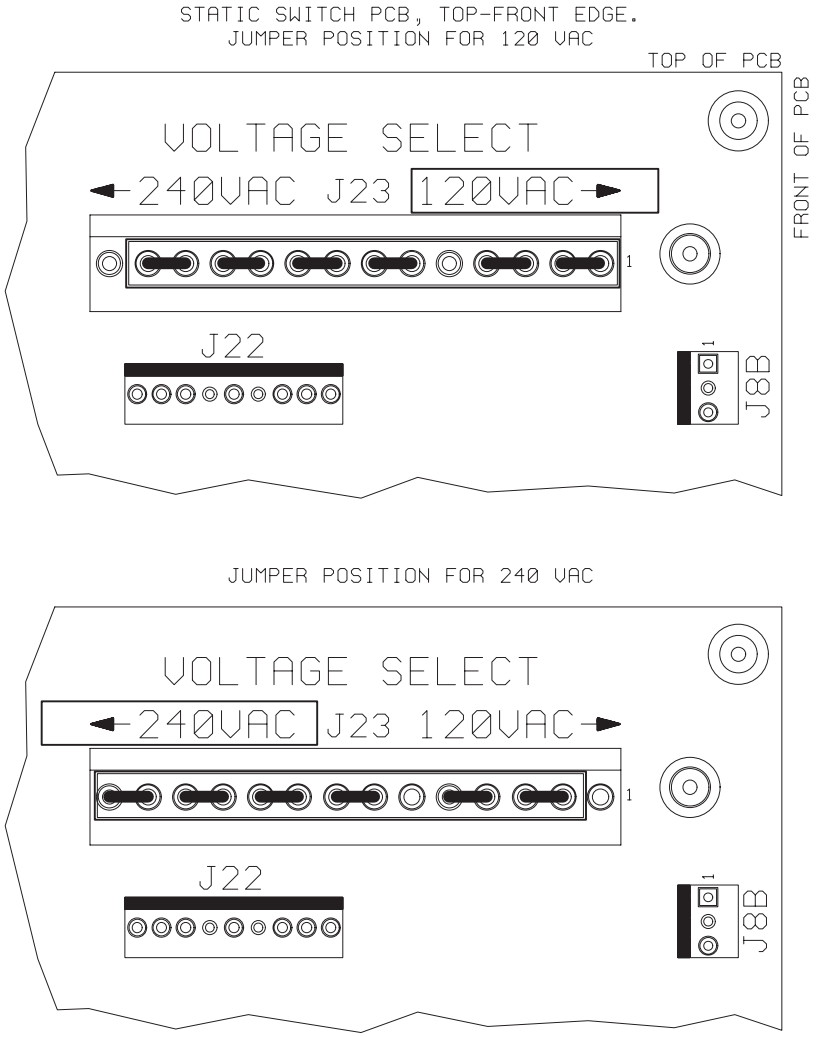
Suggested circuit breaker ratings:

Inverter rating	3.5 kVA	7 kVA	10.5 kVA	14 kVA	17.5 kVA	21 kVA
AC breaker rating	30A	60A	100A	125A	150A	200A

2.3.1.2 DC Input Circuit Breaker

Due to tremendous amounts of short circuit current available (in excess of 1000Amps for as long as several minutes!) from bank(s) of batteries, that supply electrical power to inverter systems, it is extremely important to connect a properly sized DC circuit breaker at the DC input cable that feeds the inverter system. The following table is provided as a guide for selecting the proper circuit breaker.

Figure 2-3: Static Switch Jumper Positions



Suggested DC circuit breaker ratings:

Inverter rating	3.5 kVA	7 kVA	10.5 kVA	14 kVA	17.5 kVA	21 kVA
DC breaker rating	125A	250A	375A	500A	650A	750A

2.3.1.3 Connections

All DC input connections are made through the “knock-outs”, located in the top or left side panel. Refer to Figure 2-1. Make sure that the upstream source DC circuit breaker and AC circuit breaker (if applicable) supplying the inverter are in the off (or open) position. DC input power cables should be sized such that the maximum voltage drop between inverter bus bar terminals and battery terminals is less than 1.0 volt at the breaker current rating. See paragraph 2.3.1.2 for breaker rating verses kVA rating. The inverter can accommodate three positive wires and three negative wires. Two hole lugs, compression dipc with hole spacing of 1: should be used. All ground connections should be made first, then positive (+) DC input cable should be connected, then the negative (-) connection last. The DC input landings are marked (+) and (–). Insert the input DC power cable through the selected top or side panel “knock-out”. Connect the positive (+) cable to the upper terminal connection and the negative (–) cable

to the lower terminal connection landing. Note that there is room for three lugs with two holes spaced one inch apart. Cables and terminal lugs are not furnished with the inverter and must be ordered separately for the 3.5 kVA to 145 kVA units. The 17.5 kVA and 21 kVA inverter require the super flexible (fine strand) wire, which is supplied as an option with the Maintenance Bypass unit.

The utility input and output cables are connected to a screw type terminal block. Connect the ground wires first, then the white neutral wires, then connect the black AC input wire (if applicable) and the black AC output wire. A separate, optional "Maintenance Bypass" unit and a "Power Distribution" panel (200A Square D "QO" type of circuit breakers) is available.

2.3.2 AC Input/Output Voltage Selection

The inverter is preset at the factory for 120VAC input, ON-LINE, 120 VAC, 60 Hz output.

If the input voltage or for your installation is different (200VAC to 240VAC), the following procedure MUST be followed. In the "Static Sw" area, there is a printed circuit board mounted to the right side panel. A multi-pin connector is located on the printed circuit board, close to the "Static Switch" front panel, identified as J23. This connector has 13 pins. Its mating plug has 12 positions, with interconnecting wires. This allows the jumper plug (P13) to be installed in one of two positions. When this jumper plug is in it most forward position (closest to the front panel), the unit is set for 100-120VAC operation. Removing the plug and installing it in its rear most position selects 200-240VAC operation. Verify that this plug is in the proper position before applying any voltage to the inverter system. See Figure 2-2.

EMI filer wiring. There are two separate inverter AC output EMI filters. Each filter provides one half of the output power to the system. These filters must be connected in parallel for 100-120VAC output or connected in series for 200-240VAC output. There are only two wires connected to these two filters. The "Neutral" wire, with the white band, is connected to the lower EMI filter left-hand stud. The "AC output" wire is connected to the upper EMI filter right-hand stud. In the 100-120VAC configuration, the left-hand studs of the EMI filters are connected together by a copper bus bar strap and the two right-hand studs of the EMI filters are connected together by a bus bar strap.

To change to the 200-240VAC connection, remove the wires and bus bars from the output terminals of the EMI filter. Install the copper bus bar between the lower EMI filter right-hand stud to the upper EMI filter left-hand stud. Re-connect the white "Neutral" wire to the lower EMI filter left-hand stud and the "AC output" wire to the upper EMI filter right-hand stud. Replace the hardware (flat washer, lock washer, and nut) and tighten the 10MM nuts to the prescribed torque, 35.4 inch-lbs (4 Nm). Refer to the decal on the cover plate of the static switch for strap positions. Again, verify that P23 plug on the "Static Switch" printed circuit board (located on the right side panel, is in the 240VAC, rear most position before applying any voltage to the inverter system. The extra copper bus bar may be discarded. Replace the top cover of the "Static Switch" and secure it with the three previously removed 6-32x1/4" "Phillips" head screws.

2.3.3 Software Configuration Set-Up

A "Lap-Top" Personal Computer (PC) with the "Field Service Set-up" software for the S4 inverter family needs to be available and connected to the DB-9 connector of the "Display" panel via the appropriate cable. In systems that do not have the redundant controller printed circuit board, there is no need to open the "Display" panel or remove the redundant controller. Go directly to step 3.3.2.

2.3.3.1 Dual Processor Set-Up

The following procedure should be followed for systems that contain a redundant (second) microprocessor. Using a #2 "Phillips" screw driver, remove the two screws securing the "Display" panel to the "Receiver" rack. Swing the panel forward, but do not detach it from the rack. Using the "Phillips" screw driver, remove the two screws holding the microprocessor boards in place. The circuit board securing bracket is also a circuit board extractor. Using this bracket, pull the top microprocessor circuit board out slightly so that it is disengaged from its 70 pin edge plated

connector. Swing the “Display” panel back to its vertical position and install the two screws to hold the panel in position. Do not tighten the screws very much, since they will be removed again.

2.3.3.2 System Personalization

Before installing the power modules into the receiver rack, apply the 48 DC input voltage (44 to 56VDC). The controller (microprocessors) within the unit should become activated. The “Status” indicators on the “Display” panel should sequence through their self test mode, changing from “red” to “yellow” to “green”, then momentarily off in approximately 4 seconds. After this, ignore all the LED displays. Using the “Lap-Top” PC, call up the “Filed Service Set-up” program. In the “Windows” menu, select the desired AC output voltage, frequency, and modes of operation*. The “Windows” menu will appear similar to the following:

TYPICAL “WINDOWS SET-UP MENU

AC output voltage	100	110	115	120
AC output voltage	200	220	230	240
Output frequency	50 HZ	60 HZ		
Restart	AUTOMATIC	MANUAL RESTART		
AC bypass available	YES	NO		

After the selections are complete, click on the “GO” box. The data will be sent to the appropriate address in the controllers “EEROM”. Data will be fed back as text to the screen so as to verify that the “EEROM” was set up properly. Verify that data sent is correct, or repeat this step until the correct data is obtained. Remove the applied 48VDC to the system by turning off the main DC feed circuit breaker.

*Note: This software has not been developed at present.

2.3.3.3 Redundant Controller Set-Up

After making sure the 48VDC power has been removed from the unit, remove the two “Phillips” head screws from the “Display” panel as above. Re-install the top “controller” printed board that was previously partially removed. Using the circuit board retaining bracket, disengage the bottom “controller” board from its connector. Replace the “Display” panel and secure it with the two “Phillips” head screws previously removed. Repeat step 3.3.2 for this second “controller”. When the set-up is complete, remove the 48VDC applied to the system. Again open the front “Display” panel and reseat the bottom “controller” circuit board. Replace the circuit board retaining bracket and secure it in its final position using the two 6-32 “Phillips” head screws. Replace the “Display” panel and secure it to the rack using the two 8-32 x 3/8” “Phillips” head screws. Set up is complete.

2.3.4 Power Module Installation

The power modules are designed to be “hot swap”. However, for initial start up, all of the power modules should be installed. In a system where all of the module positions are not used, reinstall the previously removed blank panels in these locations. Install the “power modules” and tighten the four thumbscrews on each module. Before turning on the main source DC circuit breaker and utility AC circuit breaker (if used), make sure that all of the “power module” circuit breakers (upper left-hand corner) of each module is OFF. Also verify the ON/Stand-by” switch on the “Display” panel is in the OFF (down) position. The inverter plant usually supplies power to some type of distribution circuit breaker panel. Confirm that all of these circuit breakers (loads) are OFF before starting up the inverter. After the DC input cable, utility line cable, and output cable are properly connected and secured, the inverter system is ready to be turned ON.

2.3.5 Start-Up Sequence

Confirm that all power modules’ ON/OFF circuit breakers are set to the OFF position. On the LCD “Display” panel, be sure inverter switch SW1 is set at OFF position.

2.3.5.1 Power-Up Procedure

Turn the main source DC input circuit breaker ON to apply 48VC to the system. The "controller" boards and LCD "Display" panels are now energized. The following message will be displayed (paragraph 4 of chapter 1 gives full details of LCD readout):

Line 1:	INV:	off	normal
Line 2:	BYP:	static	AC LOW

If the system is equipped with two controllers, one controller will take control of the system, the other will be a back-up. Assuming "Controller A" takes control of the system, the BYPASS Status LED (DS1) will be red, Inverter Status LED (DS2) will be out, "Controller B" Bypass and Inverter LEDs (DS3, DS4) will alternately blink On and Off, red for Bypass, green for Inverter. If "Controller B" takes control, its Status LEDs will be as for "Controller A" above.

If an external AC power source is used, turn on the source AC circuit breaker. After about 20 seconds the LCD should display the following information:

Line 1:	INV:	off	normal
Line 2:	BYP:	static	normal

The "Status" LEDs will be as above, except the "Bypass" will be green if the AC input voltage is within proper limits (voltage and frequency).

2.3.5.2 Powering Up the Inverters

DO NOT turn on the inverter switch SW1 yet! Turn the circuit breaker on each power module to the ON position. The LCD "Display" panel is still displaying the above two lines. Now, everything is ready and the inverter switch, SW1, can be turned ON (push-up). The "Status" LEDs will be as above, except that the "Inverter" indicator that was out will now be green if the system is functioning properly. The inverter is now supplying the power to the system. Using a voltmeter, verify that the proper voltage (100, 110, 115, or 120VAC) exist at the Power Distribution panel, or 200, 220, 230, 240VAC exist if set for the higher output. System circuit breaker may now be turned ON.

2.3.6 De-Energizing the System

If the system is equipped with an AC input, turn off the main feed circuit breaker. Then turn switch SW1 to the "Standby" position (push down). Next, turn all the power modules front panel circuit breakers OFF. Lastly, turn the DC input supply circuit breaker OFF.

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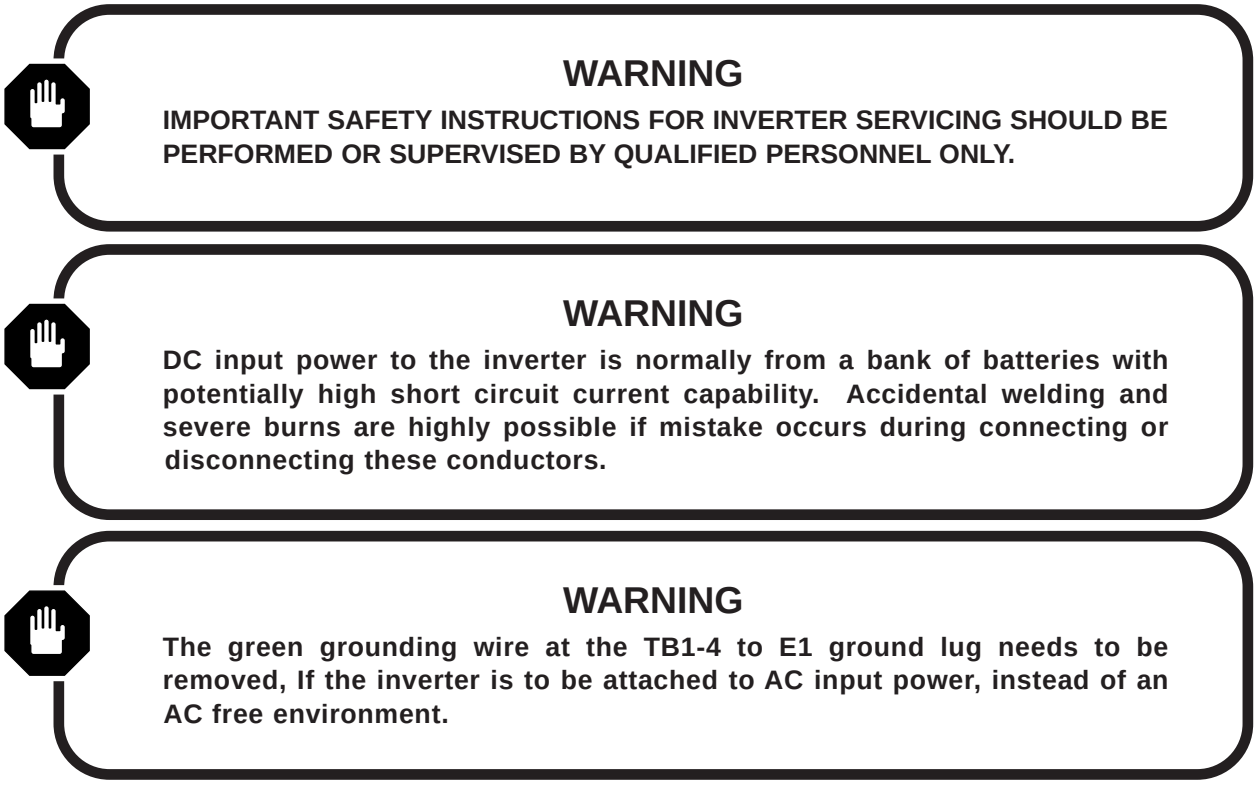
Maintenance

3.0 Scope

This chapter describes maintenance and service of MGE UPS Systems Modular Inverter System, including safety instructions, preventive maintenance, descriptions of replacement kits, and service.

3.1 Safety Instructions

IMPORTANT SAFETY INSTRUCTIONS FOR INVERTER SERVICING SHOULD BE PERFORMED OR SUPERVISED BY QUALIFIED PERSONNEL ONLY.


WARNING
IMPORTANT SAFETY INSTRUCTIONS FOR INVERTER SERVICING SHOULD BE PERFORMED OR SUPERVISED BY QUALIFIED PERSONNEL ONLY.
WARNING
DC input power to the inverter is normally from a bank of batteries with potentially high short circuit current capability. Accidental welding and severe burns are highly possible if mistake occurs during connecting or disconnecting these conductors.
WARNING
The green grounding wire at the TB1-4 to E1 ground lug needs to be removed, If the inverter is to be attached to AC input power, instead of an AC free environment.

3.2 Preventative Maintenance

3.2.1 Preventative Maintenance Procedures

The following preventive maintenance routines should be considered as a minimum requirement. Your installation and site may require additional preventive maintenance to assure optimal performance from MGE UPS Systems static inverter system and its associated equipment. We strongly recommend a contract with MGE UPS Systems Electronics Customer Support Services for preventive and remedial maintenance.

The technician or electrician performing preventive maintenance on the inverter must be familiar with the indicators, control methods, and operation of the inverter as described in this manual. All power to the inverter must be removed.

3.2.2 Dust Removal and Exterior Cleaning

Ensure that all equipment is clean and free of loose dust, dirt, and debris. The exterior of all enclosures may be cleaned with a mild solution of soap and water (only when unit is safely powered down), lightly applied with a lint-free cloth.

3.2.3 Air Intake Cleaning

Inspect the air intake and exhaust openings for blockage. Verify that air flows freely through the equipment. Clean the air intake and exhaust openings with a vacuum and a soft brush.

3.2.4 AC Fan Replacement Procedure

Every five years, replace the two AC fans on the “Static Switch” front panel, (MGE UPS SYSTEMS part number 04-22130). This is accomplish by removing all the DC and AC power to the unit by turning OFF the main AC and DC source circuit breakers. Then perform the following steps.

- Remove the front panel from the “Static Switch” (panel with two fans), by using a #2 “Phillips” screw driver to take out the four screws securing the panel to the “Receiver” rack. Unplug the two fan wires at the “Static Switch” printed circuit board. Observe the position of the connectors on the fans and the fan guard orientation. It is important that the new fans be installed in the same position as the old fans. Remove the fans from the panel. Disconnect the wiring harness from the old fans, as it will be used for the new fans.
- Install the new fans onto the panel, making sure the fan guard orientation is proper and the connector location is correct. Install the wiring harness removed from the old fans.
- Install the fan assembly onto the “Static Switch”, making sure to plug fan’s back into the “Static Switch” printed circuit board connectors. Secure the front panel in place by using the four “Phillips” head screws previously removed.
- Power up the system in the normal way by making sure the “Display” panel ON/Standby switch is in the “Standby” position, all of the power module circuit breakers are OFF before AC or DC power is re-applied to the system. Apply the 48VDC and the AC (if applicable), then turn ON each of the DC circuit breakers on the power modules, then activate the system by turning ON the ON/Standby switch on the “Display” panel.

3.2.5 DC Fan Replacement Procedure

Every five years, replace the DC fan in each power modules (MGE UPS SYSTEMS fan part number 43-153645-00). This is accomplished by removing the power module from the receiver. Then perform the following steps.

- Remove the front panel from the power module by removing the six “Phillips” head screws securing the front panel to the chassis, the two screws securing the top cover to the front panel (6-32 x _” “Phillips” head screws), and the two screws hold the DC circuit breaker to the front panel. It should not be necessary to remove the top cover.
- Remove the front panel, being careful to unplug the fan from the printed circuit board.
- Observe the orientation of the fan wires and the fan guard so that it will appear like all other power module front panels. Remove the fan from the front panel by removing the four screws holding the fan, panel, and fan guard together.
- Install the new fan in the reverse order of disassembly. When installing the front panel onto the chassis, care must be taken to ensure the three LEDs project through the front panel. Install all ten flat head screws.
- Make sure the circuit breaker on the front panel is in its OFF position.
- Install the module back into the receiver rack.

3.3 Replacement Parts

Replacement parts are available from MGE UPS Systems. Contact MGE UPS Systems Customer Support Services for ordering replacement parts. Having replacement parts on hand will prevent unnecessary delays in critical service times.

3.4 Troubleshooting and Servicing

Should you encounter a problem in the operation of the inverter and need MGE UPS Systems to service your equipment, it is recommended to leave the unit in its current state. Record message (if any) and color signals on the LCD display and LED indicators on the "Display" panel, then call MGE UPS Systems Customer Support Services at 1-800-225-7822 for assistance. Leaving the unit in its current state will facilitate Tyco field engineers to troubleshoot and bring your equipment back on line more easily. If you cannot wait, you may want to consider the following troubleshooting tips.

3.4.1 Installation Check

Often, operation problems are caused by incorrect installation or setup. Before turning the system on, review Chapter 2 for instructions pertaining to your particular system. Use the checklist in Table 4-1 in this review. If the system fails to operate properly after being turned on, all items in Table 4-1 need to be rechecked and verified to make sure things are connected correctly.

Table 3-1: Installation Checklist (Installed item to be verified)

- Inverter System included static transfer switch
- DC input terminals have correct voltage polarity
- Utility input terminals have correct voltage connections
- AC output terminals voltage connections
- Input conductor size correct ampacity
- Output conductor size correct ampacity
- Correct output voltage selected in personalizations
- Correct frequency selected
- On/Off Line Inverter is on-line
- Automatic or manual start is selected

3.4.2 Inverter System Basics

AC Input Circuit Breaker Ratings

Inverter rating	3.5 kVA	7 kVA	10.5 kVA	14 kVA	17.5 kVA	21 kVA
AC breaker rating	30A	60A	100A	125A	150A	200A

3.4.2.1 DC Input Circuit Breaker

Due to tremendous amounts of short circuit current available (in excess of 1000Amps for as long as several minutes!) from bank(s) of batteries, that supply electrical power to inverter systems, it is extremely important to connect a properly sized DC circuit breaker at the DC input cable that feeds the inverter system. The following table is provided as a guide for selecting the proper circuit breaker. Refer to 2.3.1.2 for DC input specifications.

Inverter rating	3.5 kVA	7 kVA	10.5 kVA	14 kVA	17.5 kVA	21 kVA
DC breaker rating	125A	250A	375A	500A	650A	750A

3.4.2.2 AC Output Circuit Breaker

It is not required, but highly recommended. A power "Distribution" panel is available from MGE UPS Systems at a nominal cost. Order part number XXXXXXXXX, which will accommodate up to 24 single-pole circuit breakers, "Square-D" QO type.

3.4.2.3 Cable Connection and Static Switch Module

All input and output connection terminals are mounted inside the built-in "Static Switch". It is very easy to identify this module by looking at a front panel that has twin cooling fans. This front panel can be opened with a #2 "Phillips" screw driver. When making connection, always double check to make sure that DC cable goes to DC bus bars, identified as (+) and (-). The utility cables go to a terminal block, 120/240VAC connects to TB1-2, NEUTRAL to TB1-4. AC output is from TB1-1 (120/240VAC), NEUTRAL to TB1-3. One of the best ways to verify continuity is to use a DMM.

3.4.2.4 ON-LINE Mode

ON-LINE mode is the mode in which the load is powered by the invert system, not the utility. It will get clean, transient free electrical power from the inverter system, which is producing the AC power from a DC power source.

3.4.2.5 OFF-LINE Mode

OFF-LINE mode is the mode in which the load is powered from the Utility power line (external AC input power). In the event of a power failure, a static transfer switch will connect the system output to the inverter and activate the inverter so as to provide continuous power to the load with no interruptions of power to the load.

3.4.2.6 Troubleshooting Guide

After having thoroughly reexamined the installation and setup of the system, and still found it un-operational, user can follow Table 3-2 to identify a problem, its cause, and recommendations for fixing it.

Table 3-2: Troubleshooting

Problem	Possible Cause	Possible Solution
Display panel not illuminated	No power to system	Check AC % DC power sources.
No output voltage	SW1 not ON	Turn SW1 ON
System starts, then shuts down almost immediately	Overload, or shorted output.	Remove some of the load and restart the inverter.
Power module LED turn red	Module faulted	Reset by recycling circuit breaker
Module temp. indicator on	Module fan failure	Replace module or cooling fan

3.4.2.7 Inverter Configuration

3.4.2.8 Battery Booster

Battery booster is a push-pull type converter on which average current-mode control scheme was employed for better dynamic response. The circuit utilizes a high frequency transformer for obtaining a pair of +213.5/-213.5Vdc output and for galvanic isolation as well.

3.4.2.9 Dual Half-Bridge Inverters

In or to provide more choices of output voltage, two identical half-bridge inverters are used to produce either 120VAC or 240VAC depending on parallel or series connection of the outputs. A network that consists of a coupled inductors and high frequency capacitors form a second-order low pass filter and is connected across at each inverter's output for removing PWM signal. See figure 4-4.

3.4.2.10 Average Current Mode Control

A microprocessor is employed in the inverter system to generate a reference sine wave via one of its three PWM outputs. The PWM signal is filtered to make a clean sine wave. This sine wave is applied to a voltage error amplifier.

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Theory of Operation

This chapter describes the theory of operation of the S4 inverter system.

4.0 SCOPE

The following is a brief description of the mechanical configuration and how the S4 inverter system functions. It is not intended to provide complete details of all of the circuits within the unit, but gives some details as to the function of each block. The system is a modular 48VDC to 120/240VAC inverter, which consists of 3.5 kVA/3KW modules housed in a "Receiver" cabinet. Inverter systems can be ordered with one to six power modules (3.5 kVA to 21 kVA). Inverter systems are available in the following power levels: 3.5 kVA/3KW, 7 kVA/6KW, 10.5 kVA/9KW, 14 kVA/12KW, 17.5 kVA/15KW, and 21 kVA/18KW. The inverter is designed to be a N+1 redundant system. Redundancy, or increased power capability can be added at a later date by adding more power modules. Figure 4.1 is a block diagram of a 21 kVA inverter. Figure 4.2 is an electrical block diagram of the "Inverter" system.

"Receiver" Cabinet Configuration

See Figure 2-2 for System Component Descriptions of the 7 kVA. On the top left-hand side of the "Receiver" cabinet, two "Controllers" printed circuit boards are installed, one on top of the other. On top left-hand side of the "receiver" is an alarm relay printed circuit board. The top part of the "Receiver" cabinet is common to all power level configurations. In a 21 kVA system, immediately below the "Controller" are three 5.25" high "Power Module" chassis. Below the three power modules is a 5.25" high "Static Switch". The "Static Switch" in an integral part of the "Receiver" as are the inverter output EMI filters, AC input/output terminal block, AC output and back-feed current sensing transformers, and DC input termination bus bars. Three more "Power Modules" are installed immediately below the "Static Switch". In the "Static Switch" area, provisions are made for the user to select either 120VAC or 240VAC output. This is accomplished via bus bar strap selection on the output terminals of the EMI filter and positioning a jumper plug on the Static Switch gate driver PCB, which is located on the side of the receiver.

4.1 "Receiver" Cabinet "Controller"

In the "Receiver" cabinet is a printed circuit board called a "Controller" which has a microprocessor (Intel 80C198KC), Read Only Memory (Waferr Scale "PDS301), and other associated electronics. This "Controller" is the "brain" of the system and operates the power modules and "Static Switch". As an option, two "Controller" boards can be installed which will provide redundancy. The "Controller" circuit boards are located in the top right hand side of the "Receiver" cabinet. If the redundant option is selected, only one processor operates at a given time. If the operating micro should "get lost", that is, not go through the code string properly in the allotted 250 micro-seconds, its hardware "watch dog" timer will expire, issue a reset signal, at which time the faulty micro will be disconnected from the system. The redundant micro will become activated. The microprocessors has eight analogue inputs, thus it inspects the AC input voltage, AC load voltage, AC output current, AC back-feed current, DC input voltage, DC input current, number of power modules installed, and number of power modules operating.

4.2 LCD "Display" Panel

The processor front panel, called a "Display" panel has a two line, twenty character "Liquid Crystal Display" (LCD) and a scroll switch. This will allow the operator to "scroll" through the display for reading the AC input voltage, frequency, AC load voltage, DC input voltage, DC input current, output watts, percent load (higher of VA or Watts), number of power modules installed, and number of power modules operating. Each processor has "STATUS" LEDs associated with it, each LED being tri-colored. One STATUS LED is for Utility power, the other for inverter. Two red "blown fuse" indicators are located on the top right-hand side of the "Display" panel, which give the status of the output filter capacitor fuses. These LEDs will be illuminated if a fuse is blown. There is a DB-9 connector for the RS-232 communication, and a master inverter ON/Standby switch. This switch is a rocker switch and is recessed in the front panel so as to require deliberate action by the operator to turn the system "ON" or to "Standby.

Figure 4-1: Block Diagram of the 21 kVA Inverter System

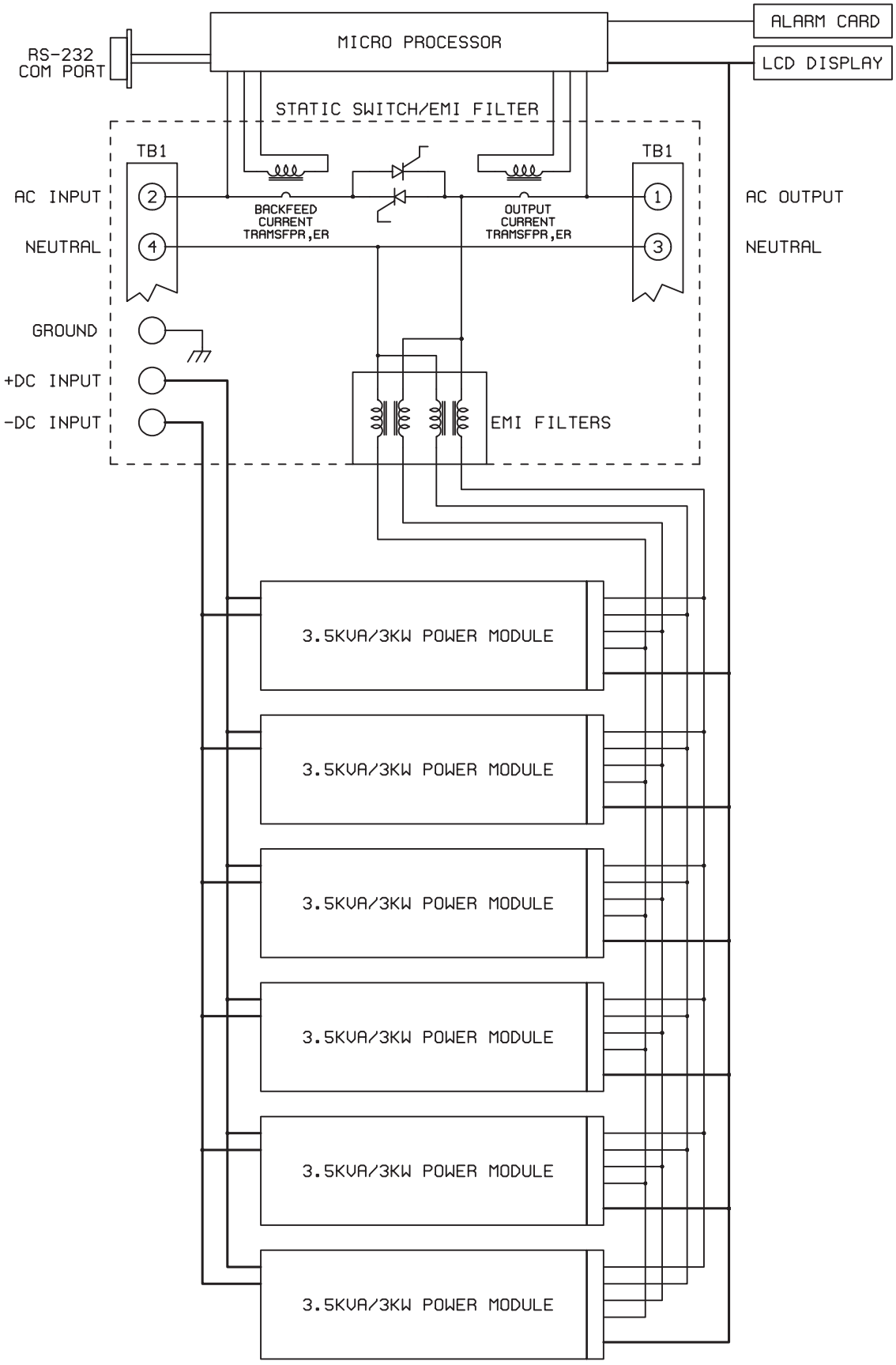
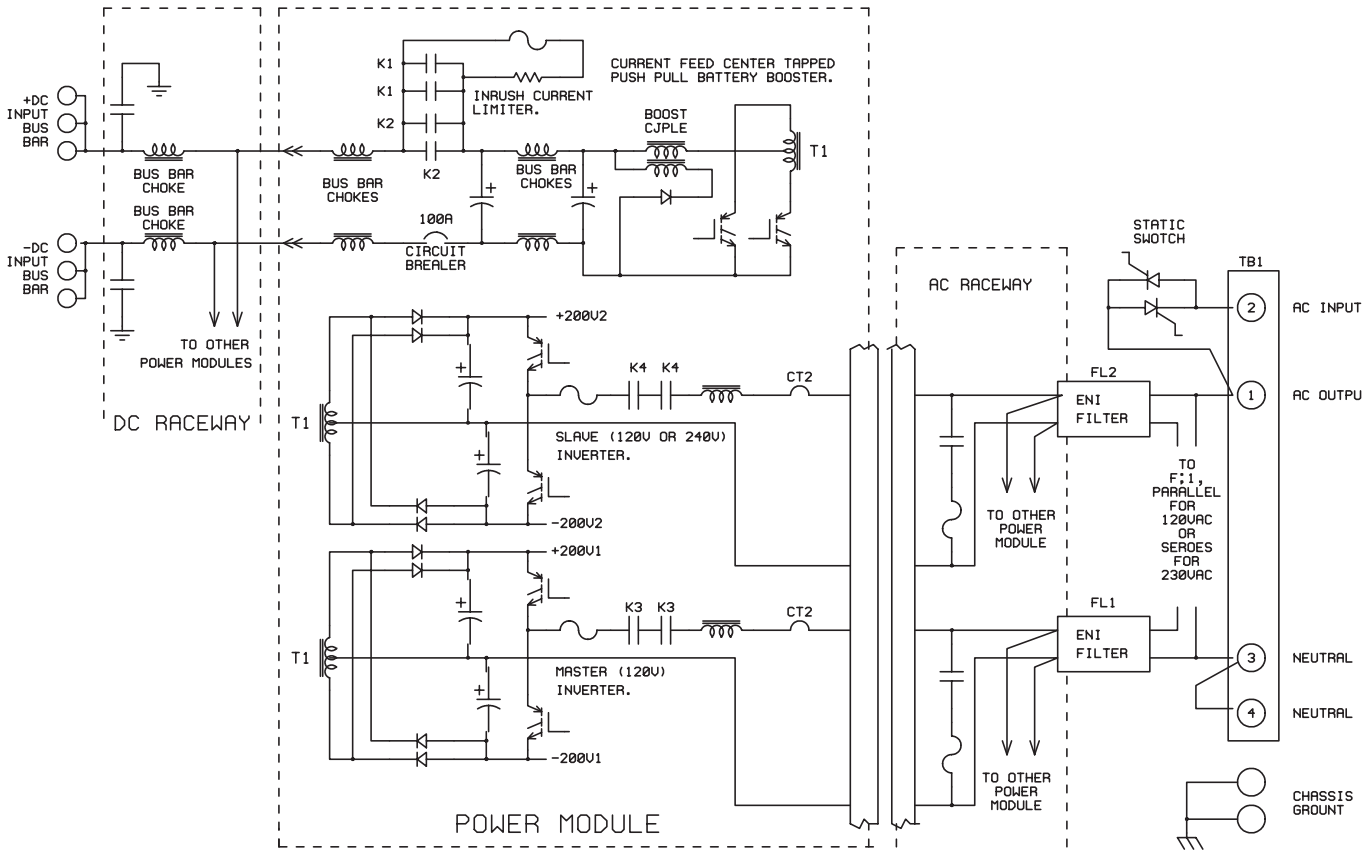


Figure 4-2: Block Diagram of the S4 Inverter Power System



4.3 Alarm Relays

Located just to the left side of the "Controller" printed circuit board card cage is the "Alarm" relay board. This is a plug in circuit board with a terminal block located on the front of the card. Wire routing to the card will be through a knock out located near the DC input, AC input/output knock out landings. A small hole in the "receivers" sheet metal, with a grommet that can be used to feed the wires up to the front of this printed circuit board. The board can be pulled out part way so as to make easy connections to the terminal block and then slid back into its connector. An optional alarm circuit board (pending) which will allow the board to "talk" to the processor board via the RS-232 communications port.

4.4 Installation Set-Up

A lap top personal computer (PC) is needed to set the system up when it is installed at the customer sight. Set up involves selecting the AC output voltage for either 120VAC or 240VAC via copper bus bar strapping on the EMI filter and jumper plug position selection on the "Static Switch" printed circuit board, which is located on the left-hand side panel in the "Static Switch" area. Each power module has two inverter outputs of 120VAC each, which can be connected in parallel for 120V or series for 240VAC. The PC is needed to tell the processor the output voltage strapping so that it can calculate output power correctly. In addition, the output voltage level can be programmed, either 100, 110, 115, or 120VAC. The 240V connection will be twice this level, that is, 200, 220, 230, or 240VAC. In addition, the ON-LINE or OFF-LINE, 50Hz/60Hz, AUTOMATIC or MANUAL restart mode can be selected. The customer MUST use the lap top PC and service software set up program to input the number of power module positions available in the receiver rack so as to obtain the correct display readings. The correct "Burden" resistor set is set at the factory. In addition, the DC current sensor used to measure the DC input current changes from model to model, thus the "Controller" must be programmed to match the kVA rating of the "Receiver" cabinet.

4.5 DC Input Power Connections

The “Receiver” cabinet also contains the DC distribution bus bar system, which is called a “DC Raceway”. It consists of a sheet metal enclosure with two copper bus bars, 1.5” wide, 0.125” thick. These bus bars have ELCON connectors attached to them. The “power modules” have short bus bars projecting out the back of the chassis, which supply the power to the module. These bus bars plug into the ELCON connectors. DC input wiring connections to the bus bars is in the “static switch” area. They are set up to accommodate three positive wires and three negative wires of 2/0 or smaller gauge wire, terminated with two-hole lugs. Wiring to the “receiver” rack should be by the “super flexible”, welding cable type wire for the five or six “power module” systems, standard wire for the one to four “power module” systems. Within the “static switch” area, the negative bus bar passes through a “LEM” open loop DC current sensor, HTA type. In a system, which has redundant “processors”, there will be two current sensors. The model number of the “LEM” current sensors change, depending upon the number of “power module” positions in the “receiver” rack. The “Controller” needs to be set up at the time of installation. This set up will be by a “lap top” personal computer (PC) and field service software.

4.6 Inverter AC Output Distribution

The AC Raceway contains connectors for interfacing to the “power modules”. It consists of one or two printed circuit boards housed in a sheet metal enclosure. These PCBs have the inverter AC output filter capacitors. These capacitors are connected to the AC output terminals and rated at 50uF, 250V, one capacitor for each 120VAC “power module” output. Power output and control of the power module is through a rack and panel connector. These connectors, one per power module position, have the control and AC output wires. Two 16Awg wires are paralleled for each 120VAC output and return. AC output wires are identified as “120VAC” and “NEUTRAL” for the master inverter, “ACHI” and “ACLO” for the 120V slave inverter. The output of these PCBs are connected to the EMI by means of 10Awg colored wire. Neutral is “white”, 120VAC is “black”, ACLO is “blue”, ACHI is “red”. These wires eventually end up connecting to the “EMI” filters, there being two 120VAC filters. “120VAC” and “Neutral” connect to the bottom EMI filter, and “ACHI” and “ACLO” connect to the upper EMI filter. The output of the filters are connected either in parallel to produce 120VAC or series to produce 240VAC. Copper straps perform this function and easily changed by the user. The inverter is shipped from the factory connected for 120VAC, 60Hz operation. The “AC raceway” PCB is connected to the “Controller” back plain via ribbon cable and also to the second PCB in a two to six “power module” system. The “AC race way” has cover plates which will aid in EMI reduction and also prevent service personal from making inadvertent contact with live power wires.

4.7 Power Modules

The power modules are self-contained DC to AC inverters, minus the output filter capacitors and control circuitry (which is located on the “Controller” boards). These “power modules” should be viewed as voltage controlled current sources (or sinks). The front panel of the power module has a 100A DC circuit breaker, which is used to turn the power module ON and OFF. This is located on the top left-hand side of the front panel. The center has a fan guard, which covers the air intake of a 24VDC cooling fan. The fan is operated at reduced voltage, 14V, so as to increase bearing life. At elevated ambient, greater than 55C, full voltage is applied to the fan. The lower right side of the power module has three “LEDs” to indicate the status of the module. The LED closest to the center of the unit is a RED/GREEN indicator. When the module is turned ON, the LED will be GREEN if the power module can function properly. If it turns RED, the module has a faulted. Faults are usually due to the power module not providing the proper output current, or the internal DC voltages are to high, or the module is over temperature. There are two “Temperature” LEDs located to the right of the RED/GREEN status LED. The center LED is AMBER, which will light if the internal heat sink temperature is to high, greater than 77C. The far right side LED is a RED and will light if the internal heat sink temperature is excessively high, greater than 88C. When this LED lights, the power module will shut down and disconnect itself from the system. The power module “status” indicator will also turn RED. Over temperature Red LED will remain illuminated until the DC circuit breaker is turned OFF. Fan sped control, temperature warning, and over temperature indications are by mechanical temperature switches.

Figure 4-3: Block Diagram of Power Module

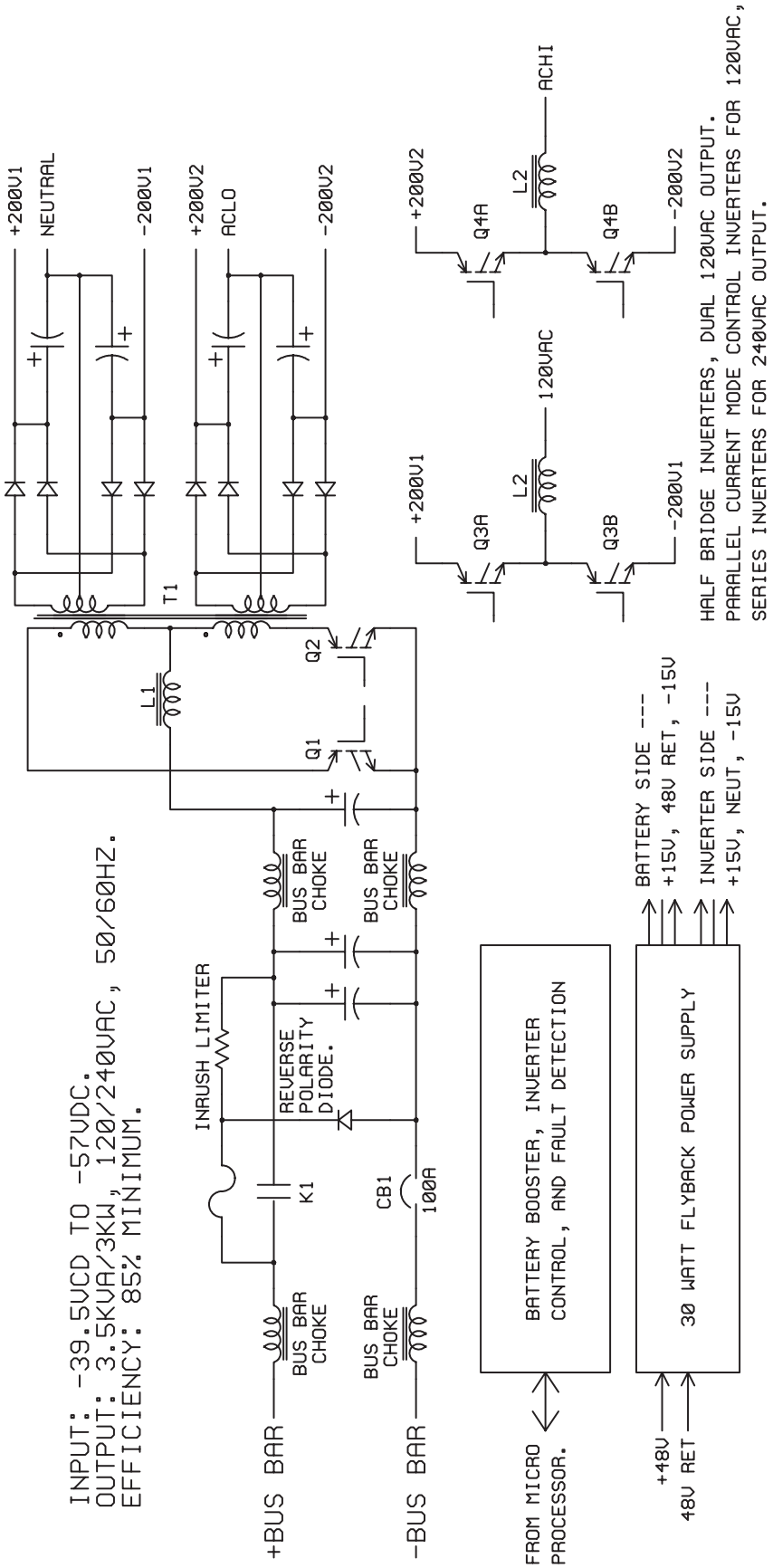
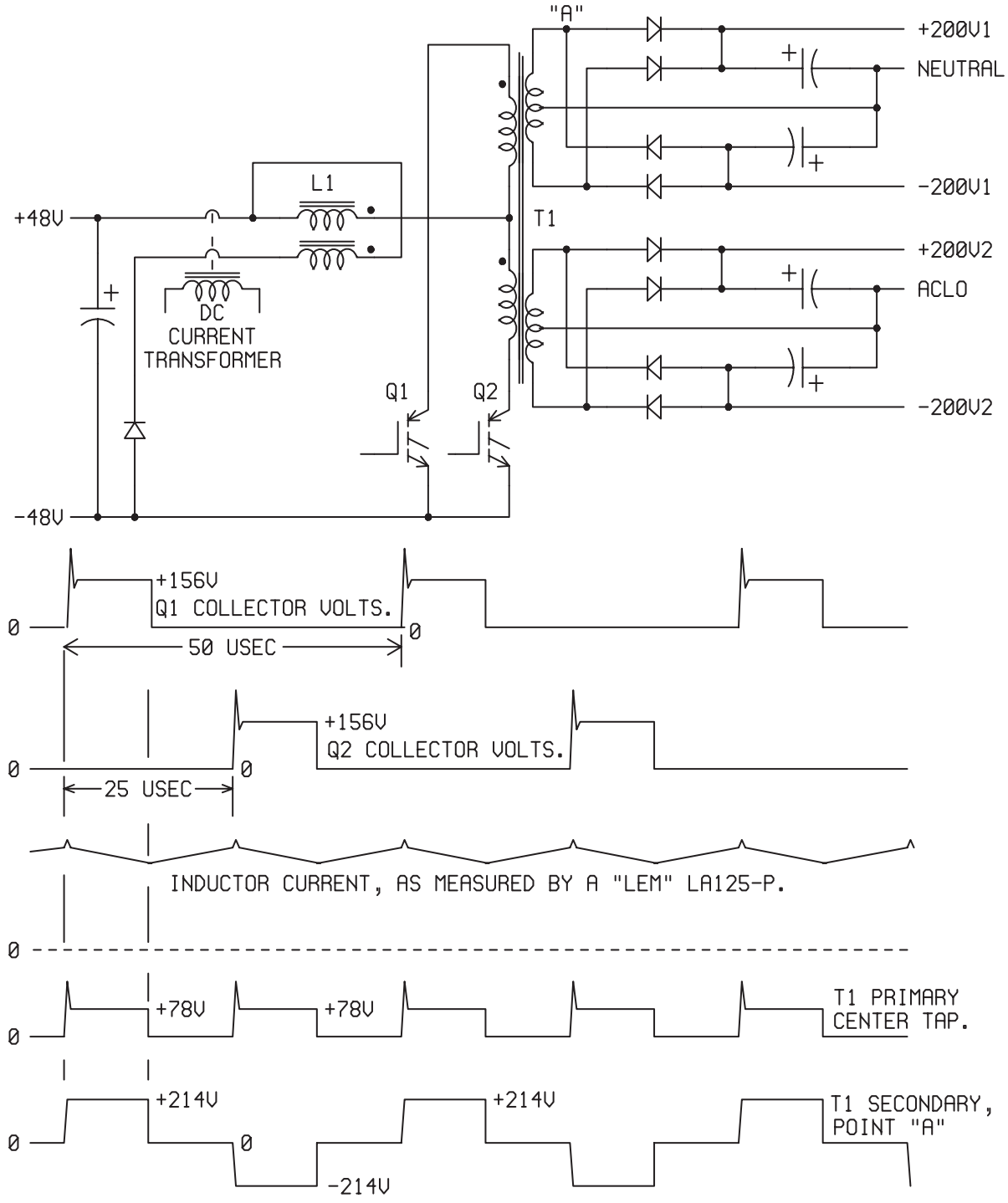


Figure 4-4: Voltage and Current Waveforms of DC/DC Battery Booster



4.7.1 Power Module Configuration

The power module output current is approximately 10A/volt when it is configured for 120VAC, 5A/volt when configured for 240VAC. Figure 4-2 to 4-4 are block diagrams of the power module. DC power enters the module via bus bars and is applied to a small EMI filter (called a "PI filter"). The filter is designed to reduce the high frequency switching ripple and noise on the battery bus. It consists of powdered iron bus bar chokes, aluminum electrolytic and polyester capacitors. A DC current sensor ("LEM" LA 125-P used to control the battery booster), inrush current control, and low DC voltage turn OFF circuitry is also located on this printed circuit board (PCB). The battery voltage, 48V, is transformed to two separate, isolated +/-212VDC outputs, which is used by the inverters to generate the AC output sine wave voltage. This "booster" is a Current Feed, Center Tapped, Push Pull (CFCTPP) converter operating at 20KHz. Circuit connection is shown in Figure 4-4 and is as described below.

4.7.1.1 Battery Input

The positive battery input, after filtering, is connected to an input inductor, L1. The output side o of L1 is connected to the center tap of a ferrite core transformer. The outside primary legs of the transformer are connected to Insulated Gate Bipolar Transistors (IGBTs). The two secondary center tapped windings on the transformer are connected to bridge rectifiers, which are located on the "Primary Snubber" PCB. The rectifiers then connect to an energy storage capacitor bank. The capacitor bank voltage is regulated to produce two separate plus 212VDC and minus 212VDC outputs. The capacitor bank (Capacitor PCB) connects to the inverter output IGBTs, which in turn, connects to the output filter inductor, then to the output connect relays before connecting to the output filter capacitors in the AC raceway by a rack and panel connector.

4.7.1.1.1 Battery Booster Operation

We will attempt to describe a typical "Battery Boost" switching cycle when the unit is operating properly. Figure 4-4 is a block diagram of the "booster". First, both IGBTs are turned ON, thus creating a short circuit on the primary winding of the boost transformer. Under this condition, the center tap of the transformer looks like it is connected to the negative DC input battery terminal through the IGBTs. Battery voltage is now applied to the input inductor. Current through the inductor builds up linearly as a function of time. The formula, V=L x dI/dT applies, where "V" is the voltage applied across the inductor, "L" is its inductance, "dI" is the rate of change in the current, and "dT" is the time increment. The choke's inductance is about 35uHy. Ripple current is set to be near 18A at 48VDC input. Ripple frequency is 40KHz, twice that of the operating frequency of the boost transformer. Under normal operation at 48VDC input, the average battery current is 72Amps for full output of 3000 watts. Thus the current in the input inductor is sweeping up and down between 64.5A to 82.5A at a 40KHz rate. When the LEM sensor, LA125-P located on the input "PI Filter" PCB measures a peak current of 82.5A, the control circuitry turns off one of the IGBTs, the other IGBT remaining ON. Because one of the IGBTs is now OFF, the current in the inductor will cause the center tap of the transformer to ramp up to the near +78 volts in about 0.5uSec (due to the snubber circuit). Due to the boost transformer's turns ratio of 4:11, the voltage reflected to the primary center tap from the 212.5V secondary will be near 78 volts ((212.5+1.35)*(4/11)=77.76). The transformer now has voltage impressed across it, so power can be transferred to the output to charge up the output bus capacitors. The capacitor voltage will be regulated to near 212.5VDC. Since the voltage on the boost choke is now reversed (output side at 78V, higher than the input side at 48V), the current in this choke starts to decrease. Note that when one IGBTs is turned OFF, the voltage on the collector of the OFF IGBT will be two times the center tap voltage, that is, 156V. When the choke current becomes less than 64.5A, the IGBT that was OFF is turned back ON, thus both IGBTs are again ON and the choke currents starts to build up again. This completes one half of the switching cycle. Next, the other IGBT that was ON in the previous power transfer cycle is now turned OFF because the choke current reached the 82.5A point, so power is again transferred to the inverters DC bus capacitors. The total time for the above switching cycle is 50uSec, or 20KHz. The waveform applied to the boost transformer is a duty cycle modulated voltage, which produces +/-212V on its output.

4.7.1.2 Inverter

The boost transformer has two secondary windings, 22 turns, center tapped at 11 turns. The two secondary windings, which are rectified, make two separate outputs of +212.5V and –212.5V each. These DC voltages are applied to a filter "Capacitor" PCB, which connects to the inverter IGBTs. The primary has eight turns, center tapped at 4 turns. The secondary inverter DC bus voltage is regulated by a TL431 shunt regulator and an optical coupler, which feeds back the control signal to the primary (battery) side electronics. The control of this Current Feed, Center tapped, Push Pull booster is by what is called "Average Current Mode Control". A write up of this basic technique can be found in the old "Unitrode" application manual.

4.7.1.2.1 Dual Inverters

There are two identical inverters. The two inverters track one another because the inverters IGBTs are switched ON and OFF at the same time and their DC bus voltages are nearly identical. Their outputs are applied to a two winding (tightly coupled) output choke, which forces the two inverters outputs to track one another. The inverter's IGBTs switch between +212V and -212V at a 20KHz rate. To generate the 120VAC sine wave output voltage, the "Pulse Width Modulated" (PWM) voltage (+/-212V) is filtered by an "L/C" filter, inductor being in the "power module" chassis, the capacitor in the "receivers" AC raceway printed circuit board. If the duty cycle is 0.5, that is, the time at the +212V rail is equal to the time at the –212V rail, the output will average out to zero (25uS at +212V, 25uS at –212V). If the IGBT switch is at +212V for 37.5uS, at –212V for 12.5uS (duty cycle of 75%), then the output voltage must average out to be +106V ((+212-V)*37.5uS =(V+212)*12.5uS), or V=106). To obtain 120Vrms (+/-170V peak), the duty cycle must range between 0.099 to 0.909. The duty cycle can be calculated from the following flux balance formula. V1*T1=V2*T2, and T1+T2=T, Duty=T1/T, where V1 is the voltage across the output choke when the positive switch (IGBT, Q3) is ON and V2 is the voltage across the inductor when the negative switch (IGBT, Q4) is ON. T1 and T2 are time at each supply rail, +212.5V or –212.5V. Control of the inverter is through what is called "Average Current Mode Control".

4.7.1.2.2 Inverter Output

The inverter's output filter capacitors (50uF/250V on each 120VAC output) are located in the receivers "AC raceway". "Hot swap" of the power modules, while the system is operating, can be accomplished with no arcing of the power module's connector pins. If the capacitors were in each power module, connector arcing would occur when the power module is installed or removed. Output fuses and disconnect relays are located in the output of each power module. The relay driver is an "avalanche rated" high voltage FET, which is allowed to "avalanche" during turn OFF of the relays. This will minimize the turn OFF time of the relays. The relays will not be energized until the inverters DC bus voltage is greater than +/-190V. As indicated previously, fuses are placed in series with each of these inverter output filter capacitors. In the event of a capacitor failure (generally shorting) the fuse will blow, thus preventing system down. In a system with three "power modules", a failure of one capacitor will not affect system performance. The fuses are located in the "cold" side of the capacitors, that is, in the "NEUTRAL" and "ACLO" side. A "blown fuse" indicator is provided on the front panel of the LCD display panel.

4.7.1.2.3 Inverter Control

As indicated earlier, the inverter is a voltage controlled current source. Control input to the power module is from the Voltage Error Amplifier, located on the "processor" printed circuit board. Control voltage scale factor is approximately 10A/V in a 120VAC system. Thus the power modules can be easily paralleled to increase the output power capability of a system. The control input to the power module is filtered, buffered by an operational amplifier, and then applied to a current error amplifier, the other input to this current error amplifier is the output current of the power module as sensed by a "LEM" LA125-P current sensor. This current error amplifier operates in what is called "average current mode control". The current error amplifier's output is summed with a triangular wave sweep signal, which sweeps between +5.2V and –5.2V at a 20KHz rate. This summed signal is now applied to a high-speed comparator, the output of which control optically coupled IGBT gate drivers.

4.7.1.2.4 Average Current Mode

If the inverter "current command" control signal can be made to control a current source (or sink), then the pole/zero associated with the output L-C filter becomes a first order system, that is, a current source discharging or charging a capacitor. It is much easier to stabilize this type of control loop. It also provides the needed current limiting function. This type of system can be implemented by summing the inverter output current signal with the "current command" signal and applying this signal to a current error amplifier. The output of this amplifier, along with a triangular "sweep" signal, is applied to a set of comparators, which operate the IGBT date drivers.

Here is a little history as to the problems associated with this approach. For an inverter to make a 120VAC sine wave output (+/-170V peak) using a +/-213VDC bus voltage, the duty cycle must range between 8% to 92%. A duty cycle of 50% will make the filtered output voltage zero. In the classical "peak" current mode control system, when the duty cycles becomes greater than 50%, the famous half cycle instability problem will manifest itself. In "current mode" controlled DC power supplies, the problem was resolved by adding what is called "slope compensation" to the current feedback signal. This works well for a fixed output voltage power supply, but not for a variable output supply. The "Unitrode" applications handbook, IC# 1051/1997 explains this instability in detail.

Later, another way was found to resolve this instability. If the "current command" signal is summed with the "output current" signal, through another error amplifier, then applied to the comparators, the instability problem is resolved. However, there are restrictions on this error amplifier. This amplified error signal is now applied to a set of comparators. The other input to the comparator is a linear sweep voltage. The maximum gain of this new current error amplifier can be made fairly high. However, the slope of the amplified signal needs to be less than the sweep generators slope (dV/dT). If it greater than the sweep generators dV/dT, the output IGBTs will be turned ON and OFF several times during a switching cycle. If this happens, the switching losses will become very large, resulting in IGBT failures due to excessive heating of the transistor. The easiest way to analyze this function is to generate a computer model and analyze the signal over the entire sine wave cycle for all load conditions, resistive, leading reactive, lagging reactive, and computer loads with crest factors up to 3:1. This program was written in TURBO BASIC, an old BORLAND software package, and is included in the appendix as INV3 kVA3.BAS. A copy can be obtained from the writer at the following E-mail address: FRANK.MILLER@MGEUPS.COM. This program should run using QUICK BASIC, whoever some of the SCREEN and PIXEL setting statements may need to be changed. It is best to run this program in the pure DOS mode, not through "Windows". "Windows" mode is about nine times slower than the DOS mode, but it will work.

4.7.1.2.5 Inverter Sweep Generator

The sweep signal is obtains its signal from the battery booster LMC555CN oscillator through an optical coupler. This 40KHz signal is applied to another D flop (U19), which divides 40KHz signal by 2 to make a 20KHz square wave. The sweep generator is almost identical to the sweep generator in the battery booster section, except it is set up to produce +/-5.2 volt sweep voltage instead of +/-9.52 volt sweep signal. This sweep generator signal is summed with the output of the current error amplifier through 4990 ohm resistors. This summed voltage, (Vveao+Vsweep)/2, is applied to a set of window comparators, one comparator uses a positive 1.00V reference, the other uses a negative 1.00V. The outputs of these comparators operate the photo drivers (HCPL-3120) which are located on the "Power Supply/Driver" PCB. If the summed voltage is between –1.00V and +1.00V (dead band), neither comparator will turn "ON" its respective photo drivers, thus all of the inverter IGBTs are OFF. This is needed to ensure that "positive" and "negative" IGBTs are not ON at the same time. This could occur in an electrically noisy environment, so the +/-1.00V "dead band" window will provide the needed noise immunity.

4.7.1.2.6 Fault Detection

For fault detection, the input "Current Command" signal, which is the output of the "Controller" Voltage Error Amplifier, is summed with the output current signal as measured by the "LEM" LA 125-P sensor. It is then filtered to remove the ripple and applied to a window comparator. Since the "output current" signal is out of phase with the input "Current Command" signal, the filtered sum should be zero if the system is functioning properly. If the sum of

the two signals is not zero, then the inverter has failed. The inverter must be disconnected and shut down. Shut down is accomplished by opening the inverters output relay as quickly as possible, turning of the drive to the IGBTs, inhibiting the battery booster, and issue a signal to the “Controller” that the module is not OK via the MODSOK signal line. A “minor” alarm signal will be issued by the “Controller” so the user will now that a fault has occurred. The voltage error amplifier on the “Controller board (“current command” signal), will increase its output so that the remaining power modules can output more current to make up for the current that was supplied by the disconnected power module. The red/green “Status LED”, located on the power modules front panel, will turned RED. Two additional LEDs are located on this front panel, an AMBER colored LED which will be illuminated if the internal heat sink is hotter than desired (and a temperature warning signal, called “NOTEMP”, will be supplied to the “processor”. If the internal heat sink temperature becomes excessive, a RED status LED will light and the power module will shut down and a NOT OK signal issued to the processor. The circuit breaker located on the front panel of the power module must be turned OFF, wait a few seconds, then turn it back ON to clear faults. Upon turn on of the circuit breaker, the module will restart if no fault exist.

4.7.1.2.7 Internal Power Supply

The power supply in the “power module”, operates from the –48VDC input and is located on the “Power Supply, Driver” printed circuit board. A 50/60 Hz bias transformer, which is located on the “Static Switch” circuit board, is connected to the utility AC input terminal block. One of the secondary windings on this transformer is used to make a -48VDC source, which is “Ored” with the battery –48VDC input. Thus the power supply will operate with either battery power or AC utility power.

The supply is a 30W discontinuous mode flyback design, operating at 100KHz, which produces plus and minus 15VDC for the battery (primary) side circuits, plus and minus 15VDC for the inverter (secondary) side circuits, and four isolated 30VDC outputs for the four isolated photo coupled inverter IGBT gate drivers. Control is via a UCC3804N integrated circuit, which drives an IRF640 FET that is connected to a powdered iron “toroid” transformer. The majority of the power is used to operate a 24V DC cooling fan. If the IGBT heat sink temperature is below 55C, the fan will be operated at reduced voltage (+15VDC) so as to increase fan life. If the heat sink temperature exceeds +55C, a mechanical thermal switch will close and the fan will receive about 26V (+15V and –11V via a resistor from the –15VDC supply). This fan power is taken from the primary (battery) +/-15VDC supplies. The “Unitrode” integrated circuits manual (now Texas Instruments) provides data as to the design and operation of UCC3804N chip.

4.8 Controller

This printed circuit board contains an “Intel” 80C196KC processor (U9), an Electrically Erasable Read Only Memory (EEROM) (U8), a “Wafer Scale Integration, Inc.” PSD301 program memory chip (U10), which contains the operating program in its Read Only Memory (ROM). It also has a Random Access Memory (RAM) section. The circuit board also has two CMOS rail to rail quad operational amplifiers (U5, U6) which buffer the eight analog inputs to the processor. Other circuitry includes a “watch dog” timer (U7), LED and relay driver (U11), power ON reset circuit (U4), reference sine wave Pulse Width Modulator (PWM) filter (U12, U13, Q5, Q6), and voltage error amplifier (U14). Power for the processor and other circuits is obtained by down regulating the -48V battery voltage. The processor is referenced to the negative 48VDC input. The positive 78VDC input is connected to “ground” at the user’s sight. Thus the negative DC input must be fused. There may be two processor PCBs in a system, so a flip flop was implemented using photo-couplers (UU17, Q10). The processor that starts up first will takes control.

4.8.1 “Controller” Power Supply

The 48VDC battery voltage is applied to a 15VDC regulator circuit which is made up of a TL431ACP shunt regulator chip and a TIP47 series pass transistor. The actual DC voltage is +14.97, +/-2%. This is applied to a LM7805 regulator chip to make the +5VDC operating voltage for the 80C196KC micro. Two other TL431ACP shunt regulators are placed in series so as to make +2.495V and +4.990V reference voltage for the processor’s eight bit A/D converter. As indicated above, the signals to the eight analog inputs of the micro are buffered by a CMOS rail to rail amplifier (LMC660) such that the input to the micro can not exceed the limits allowed by the processor manufacturer,

zero to +5V. The +2.495V is used as the reference for the LMC660 amplifiers, signal transformers, which are used to measure the AC input and load voltages, and AC current transformers.

4.8.1.1 "Controller" Input Signals

The DC current sensor used to measure the battery current is "LEM" HTA types and require +15VDC, return, and –15VDC. We do not have a negative 15VDC supply, thus the LEM was offset by 15V. The –48VDC battery line, which is called AGND ("Analog Ground" after fusing) was connected to the "LEM's" –15V terminal, the "return" was connected to +14.97V, and the +15V terminal connected to +30V. This +30V is quasi regulated by a 16V zener (anode connected to the +14.97V) and NPN transistor, TIP47. The HTA-X00 sensors are set up to produce an output of +4.00 volts at rated DC current. The model number of the HTA-X00 changes depending on the number of power module positions available in the "Receiver" cabinet. The field service setup software is needed to tell the micro how many positions are available so that the proper scale factor can be programmed into the EEROM.

4.8.1.2 DC Current Measurement

Below is a table of "LEM" model numbers to be used in the various receiver configuration.

Power Module Positions	Model Number	Current Rating	Output voltage	Max Current Measurement
1	HTA-100	100A	4.00	137.8A
2	HTA-200	200A	4.00	275.6A
3	HTA-300	300A	4.00	4133.9A
4	HTA-400	400A	4.00	551.2A
5	HTA-500	500A	4.00	689.0A
6	HTA-600	600A	4.00	826.8A

The actual maximum operating current is less than the rated current. For zero DC input current, the output of the HTA-X00 sensor will be at zero with respect to its "return", which is actually connected to +14.97V. At full rated output current, the HTA- sensor will output 18.970V (14.97+4.00 =18.97). Sensors are intended to measure AC current, thus have at lease a 141% DC measurement capability. The LMC660 amplifiers are set up to range between +4.50V to +0.50V (HTA-100 measuring range of zero to +125A). The other HTA sensors produce the same voltage swing for different current levels. The Micro scale factor is based on the number of power module positions available, not power modules installed in the "Receiver" cabinet, and must be set up properly.

4.8.1.3 Analog Inputs

The table below identifies the eight analog inputs to the processor. The input will make a voltage that ranges from +4.50V to +0.50V at the appropriate input port of the processor. Voltages to the analog input terminal of the processor, which are between 0.10 and 0.25V are usable. Voltage above 4.75V may not be processed since the minimum Vcc supply voltage to the processor is 4.75V via a linear regulator, LM7805CT or LM340T5.0.

Function	Micro port	Input at 0.250V	Input at 0.500V	Input at 4.500V	Input at 4.750V	Notes:
I backfeed	P0.0					V>+/-1V
Ibat, battery current.	P0.1	133.27	125.45	2.00	-5.72*	HTA-100
No. modules installed.	P0.2					See below
No. modules OK.	P0.3					See below
Vbat, battery voltage.	P0.4	66.613	65.030	39.696	38.113	
Vacin, RMS input volts.	P0.5	143.51	127.52	127.52	143.51	
Iacout., rms load current.	P0.6	30.23	34.02	90.68pk	102.05pk	
Vacout, RMS load volts.	P0.7	143.51	127.52	127.52	143.51	

In the chart above, (*) indicates negative current, however actual current ranges is always zero or greater. Zero current voltage is +4.565.

MODSIN and MODSOK voltage is a function of the number of modules installed. The chart below gives the expected voltage at P0.2 and P0.3. In each power module, there is a 10K resistor connected between MODSIN and AGND and also between MODSOK and AGND for each micro.

MODSXX	0	1	2	3	4	5	6
P0.2, 3	0	1.4926	2.4917	3.2056	3.7412	4.1580	4.4914

4.8.1.4 Digital Inputs

The power module temperature warning is via a photo coupler connecting the NOTEMP terminal to AGND for each processor. The processor will energize the “minor alarm” relay for this condition.

4.8.1.5 Alarm Relays

The microprocessor has a three alarm outputs:

- Major alarm will be by the de-energizing the alarm relay. Major alarm will be issued if the inverter can not support the output load requirement.
- Minor alarm, which alerts the operator to a potential problem. Voltages or temperatures which are not within limits will cause this alarm.
- “Utility” alarm relays will be energized when the AC input voltage to the inverter is not within its proper operating limits (+10%, -15%) or the utility voltage frequency is not within limits, 50 +/-3Hz, or 60 +/-3Hz. If Utility voltage is present and the system is set up to operate in the “OFF-LINE” mode, the “Static Switch” will be turned ON so as to support the load.

4.8.1.6 “Watch Dog” Timer

The processor operates from a 16MHz crystal connected to its oscillator terminals. None of the internal ROM in the processor is used. The processor must go through the code string every 250uSec. If it fails to do this, it means that the program is not being followed and is probably “lost”. A hardware “watch dog” timer is implemented with R’s, C’s, diode, and a “Schmitt” hex inverter gate. As long as the input to the timer is continuously reset, the micro will operate normally. If it is not reset, a NMI signal is issued and the micro will load in the default values from the ROM. If a redundant processor is available, the faulted micro will be inhibited and the redundant micro will be allowed to operate via the optically isolated cross-coupled gates.

4.8.1.7 High Voltage Drivers

The processor PCB also has a high voltage transistor array (ULN7002), which is used to control the tri-colored "STATUS" LEDs and "alarm relays". The LEDs are powered directly from the 48V input bus through dropping resistors. The transistor array shorts out the appropriate Red and/or Green LED to produce the Green, Amber, or Red color. The "Alarm" relays operate directly from the +48VDC supply, thus the high voltage driver is needed.

4.8.1.8 Under Voltage Detector

The "Controller" circuit board also has an under voltage detector (U4) which inspects the +14.97V regulator voltage. The "reset" line will be held low until supply voltage is greater than +12.275V. A "reset" signal is issued if the voltage falls below this level.

4.8.1.9 Sine Wave Reference

Sine wave reference signal is obtained from the 80C196KC processor, which has three PWM outputs. One of these is used to generate the phase locked sine wave reference voltage. The amplitude is set at the time of calibration and the calibration constants are stored in the EEROM. Default values are in PSD301 ROM. The output of this PWM signal is buffered (U7) and applied to an optical coupler (U12). The coupler provides isolation between the primary (battery) side circuitry and the secondary (AC output) circuitry. The optical couplers output amplitude is stabilized by a +5V regulator (U13) and FET switches (Q5, Q6) and then filtered by a two stage R-C filter (R60, R61, C40, R62, C41) than level shifted and phase corrected by C42 and R63. The buffered (U14) reference sine wave is now applied to the system "Voltage Error Amplifier", U14 through ad DC blocking capacitor. Feedback to the error amplifier is from the output of the 120VAC inverter, connections being made at the input terminals of the EMI filter. An optically coupled FET switch is placed in series with the output of the Voltage Error Amplifier so as to be able to disconnect it from the system in the advent of a failure in the processor. Isolation resistors are provided in the "Voltage Error Amplifiers" output that goes to each power module. This will prevent a system failure if one of the control lines should become shorted to ground.

4.8.1.10 "Display" Driver

Output to the LCD display is isolated by means of diodes. The LCD is powered from the 48V input supply and regulated via a 5.1V zener and diode so as to produce +5.7V for operating the LCD module. This compensates for the isolation diodes in the output of the LCD signal lines. LCD actually operates at +5.0VDC.

4.8.1.11 "Controller" Selection

The cross-coupled optical coupler (U17) and FET (Q10) generate the MASTER control signal (I/O port P1.4). A "1" to the processor tells it that it is in control. A green LED located on the processor PCB will be illuminated if the processor is operation. The LED can not be seen when the LCD panel is in place.

4.8.2 Static Switch

The " Static Switch" consists of a parallel connection of a dual Silicon Controlled Rectifier (SCR) module, anode of SCR1 connected to the cathode of SCR2, anode of SCR2 connected to the cathode of CR1. This module is mounted on a heat sink, 12" long, 5.15" high, 1.5" thick. The heat sink is cooled by two AC powered fans. The purpose of the dual fan is for redundancy. If one of the fans should fail, the other fan can cool the SCR module until the unit can be serviced. The "Utility" AC input, if available, will be connected to a terminal block TB1-2. The system output is on TB1-1. TB1-2 and TB1-4 are AC returns. TB1-2 is connected to the dual SCR module. The other side of the SCR module connects to TB1-1 and also to the "EMI" filter, which in turns connects back to inverter output. Several different SCR modules used in the system. The current rating of the modules changes with respect to the number of power module positions available in the "receiver" rack. The one and two module system will utilize an IXYS "MCC72-16io1 B", the three and four module system will utilize an IXYS "MCC132-16io-1", the five and six module system will use an IXYS "MCC220-16io". A 480V "Metal Oxide Varistor" (MOV) is connected across the SCR module.

4.8.2.1 Static Switch Driver

On the right-hand side panel of the “receiver” cabinet is the “Static Switch” gate driver printed circuit board. This board serves two functions. One, it has a 120/240VAC, 50/50Hz bias transformer mounted to it which provides the auxiliary 48VDC for operating the “Controller” and “LCD” “Display”. In addition, the transformer has two low voltage AC windings, which are used to make two isolated DC voltages, that are used to turn ON the “Static Switch “ SCRs. This transformer is connected to the “Utility” AC input. Selection of the 120VAC or 240VAC connection is by means of a jumper plug. The printed circuit board has two small transformers, which are used to measure the AC input and AC output voltage. Selection of the input voltage range, 120/240VAC, is accomplished by the same jumper plug as used to select the operating mode for the bias transformer. Each transformer has two secondary windings, one for each “Controller” of a redundant system.

When the “Static Switch” SCR module is turned ON, a connection between the “Utility” AC input and the inverter output. Under normal conditions, the SCR module is ON at all times and commanded OFF by the “processor”. Thus a “fail safe” mode of operation is provided. When the power to the load is from the “inverter” system, the “Controller” will turn ON an optical coupler on the “Static Switch” gate driver board. When these photo couplers are turned ON, the gate drive current will be turned OFF, thus the SCR module will disconnect the “Utility” AC input.

Two isolated, low voltage, DC supplies were created, one for each SCR in the dual SCR module. The voltages will range between 5 to 10 VDC, depending upon the “Utility” input voltage. “P- channel” FETs and resistors are connected from this DC supplies to the gates of the SCR module. The FETs are connected so that they are ON. That is, its “source” is connected to the positive supply terminal, the FETs “gate” to the negative supply through a resistor. The FETs “drain” connects to the SCR gate through a resistor. Photo couplers are connected between the “source” and “gate” of each FET. When the photo couplers are ON, the FET gates are shorted out, thus the FETs are OFF. With no gate drive current, the SCR modules are OFF.

4.8.3 Current Sensing

AC current transformers are used to measure the system output current and also to measure “back-feed” current. They are “Square-D” devices with a 650:1 turns ratio. There are four current transformers in a system that has a dual “Controller”. These current transformers are located on the wire going to TB1-1 (output terminal) and TB1-2, (input terminal).

4.8.3.1 Output Sensing

The “burden” resistors for the AC output current transformers are located on the “back plane” printed circuit board. This back plane is used to interconnect the “processor” PCBs, AC raceway, and “Alarm” relay PCB. A “receiver” cabinet, which can accommodate six power modules, will have six parallel 14.3 ohm resistors for each AC output current transformer. A cabinet, which can accommodate five power modules, will have hive parallel resistors. A system with four power modules will have four parallel resistors, etc. The number of parallel resistors depends upon the number of power module positions available in the rack, not the number of modules to be installed. A system which has two “:Controller” boards (redundant mode) will have two sets of burden resistors. Selection of these resistors will be via a 12 position “DIP” switch, located on the “back plane”. This switch is factory set and should not be changed by the customer. A one module system, switch position 1 and 12 will be turned ON, for a two module system, switch positions 1, 2, 11, and 12 will be ON, for a three module system, switch positions 1, 2, 3, 10, 11, and 12 will be ON. All switches will be set ON for a six module system.

4.8.3.2 Back-Feed Current Sensor

Back-feed current transformer is installed on the AC input wires. This device is necessary to determine if the “Static Switch” is functioning properly. If a SCR in the “Static Switch” should fail in the shorted mode, power from the inverter could be applied to the AC input terminals. This would present a safety hazard for service personnel working on the “utility” wiring. CSA and UL require back-feed protection. This is accomplished by the use of an AC current transformer that will sense any current flowing through the SCR when it is OFF. If current is detected, the inverter will be shut down.

The output of this current transformer is clamped to a maximum of +/-1.1V by means of back-to-back diodes, which is in parallel with a high value burden resistor. This signal is supplied to the "Controller". If back-feed current should be detected when the inverter is operating, the system will be shut down, that is, latched OFF. Reset us accomplished by cycling the system OFF ON/ switch on the LCD display panel. Current transformers are connected to the "back plain" via an eight-pin connector. Four of these pins are used as interlock connections, which will prevent the inverter from operating if the current transformers are not connected.

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Glossary

Appendix A

Symbols	Definition/Meaning
@	At.
/	And/or.
+/-	Plus or Minus.
#	Number.
°C	Degree Celsius.
°F	Degree Fahrenheit.
Ø	Phase angle.
W	Ohm; unit of resistance.
®	Trade Mark.
2nd	Second.
AC or ac	Alternating current, also implies root-mean-square (rms).
Ambient Temp.	Temperature of surrounding air.
Ambient noise	Acoustical noise of surrounding environment.
ANSI	American National Standard Institute.
AWG	American Wire Gauge.
Breaker	Electrical circuit interrupter.
BYPASS	See "Static Transfer switch".
BYPASS mode	See "off-line mode".
Carrier	The company or individual responsible for delivering goods from one location to another.
C	Common.
CB	Circuit breaker.
Conduit	A flexible or rigid tube enclosing electrical conductors.
C.S.S.	Customer Support Service.
Current rating	The maximum current that a conductor or equipment can carry reliably without damage.
dBA	Decibel Adjusted.
dBrnC	Decibel above reference noise.

DC or dc	Direct current.
Digital Meter	The LCD display on the front panel of inverter system.
Earth ground	A ground circuit that has contact with the earth.
Electrician	Refers to an installation electrician qualified to install heavy-duty electrical components in accordance with local codes and regulations. Not necessarily qualified to maintain or repair electrical or electronic equipment.
Freq.	Frequency.
Frequency slew rate	The change in frequency per unit of time. Given in term of Hz per second (Hz/sec.).
GND	Ground.
Hz	Hertz, frequency measurement unit, 1Hz is one cycle per second.
Inverter mode	See “on-line” mode.
I	Current.
IEC	International Electrotechnical Commission.
IEEE	Institute of Electrical and Electronic Engineers.
Input branch circuit	The input circuit from the building power panel to the equipment.
Inverter	An electrical circuit that generates an AC voltage source from a DC voltage source.
kVA	KiloVolt-Ampere; is equal to 1000 Volt-Ampere.
L	Line.
LCD	Liquid-Crystal Display unit.
LED	Light Emitting Diode.
Mains or Mains 1	Main AC input source.
Mains 2	Bypass AC input source.
mA	milliampere.
MAX.	Maximum.
MCM	Thousand circular mil; standard wire sizes for multiple stranded conductors over 4/0 AWG in diameter. M is from Roman numerical system indicating 1000.
Module	Refers to individual power inverter module.
N	Neutral.
NC	Normally close.
NO	Normally open.
NEC	National Electrical Code.

NFPA	National Fire Protection Association.
NO. or No.	Part number.
On-line mode	Inverter output power is the primary energy source to load.
Off-line mode	Inverter output is off, and the load connected at the inverter output receives power from utility line via a static transfer switch or maintenance bypass relay.
OSHA	Occupational Safety and Health Agency.
PWM	Pulse Width Modulation.
SCR	Silicon controlled rectifier.
Shipping damage	Any damage done to an article while it is in transit.
SPDT	Single Pole Double Throw.
Static Transfer	An solid state switching mechanism electronically controlled to pass AC power directly from the utility to an output load.
Technician	Refers to an electronic technician qualified to maintain and repair electronic equipment. Not necessarily qualified to install electrical wiring.
Test connector	DB-9 type connector on the LCD panel allowing MGE UPS Systems Customer Support Service technician to access programmable and diagnostic features of the system.
VA	Volt-amps, unit for apparent power measurement, equal V x I.
VAC or Vac	Voltage of AC type.
VDC or Vdc	Voltage of DC type.